UNEASY NEIGHBORS: WILDLIFE AND FARMERS AROUND KIBALE NATIONAL PARK, UGANDA

By

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To my parents

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By

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This study focuses on sedentary, small-scale farmers suffering crop loss to mammals (>3 kg) on the edge of Kibale National Park (KNP), Uganda, to better understand human-wildlife relations within a densely settled landscape and modern property system. Systematic monitoring of crop loss to wildlife and livestock was conducted in 6 villages around KNP over a two year period. Interviews and participatory rural appraisals were used to survey the perceptions and attitudes of local community members. Five wildlife species accounted for the vast majority of damage to crops around KNP.

Marked variation in frequency and extent of damage is reported within villages, between villages and between species of wildlife. Ninety percent of damage events occurred within 200 meters of the forest edge. Distance from KNP proved to explain the greatest amount of variation in damage although vegetative cover, guarding and hunting influenced the extent of crop damage. Elephants inflicted catastrophic damage to farms but their forays were rare and highly localized. Analysis of temporal patterns of crop foraging revealed significant associations of rainfall and damage to seasonal crops such as maize, whereas aseasonal crops were consumed most in months when preferred forest fruits were unavailable. Livestock also caused considerable damage to crops but farmers never complained about this as they had institutionalized modes of restitution for such damage. Baboons were ranked as the worst animals by farmers. Farmers' perceptions of benefits from KNP focused on illegal resource extraction. Victims of elephant damage tended not to perceive any benefits of KNP. The historical management of human-wildlife conflict in Uganda has been altered in recent times, as state ownership of wildlife prohibited traditional methods of coping with crop loss to wildlife, such as garden hunting. Currently, conflict with medium to large mammals is restricted to a narrow band of farmers living near the forest edge, but to these farmers, the risk has been amplified by legal prohibitions on killing of wild animals, some of which are endangered species. The costs of wildlife conservation at Kibale are thus borne by a community which receives

and perceives little benefit from wildlife.

CHAPTER 1

A HISTORICAL OVERVIEW OF HUMAN-WILDLIFE RELATIONS IN WESTERN UGANDA

Introduction

Ever since there has been agriculture, humans have lost crops and livestock to wild animals. The Sumerian farmers of antiquity prayed to Ninkilim, "goddess of field mice and vermin in general", lest they harm the growing grain (Kramer 1963:106). Sanskrit text from the 6th century B.C. records the devastation of the Anga Kingdom in India by wild elephants (Sukumar 1989). To tame the wilderness, humans must first "drive off wolves" (Crosby 1986:30) and protect life and property from dangerous animals. The term pest or vermin used for wild animals typifies the ancient competitive element to human-wildlife relations (Parker 1984).

Preindustrial, subsistence farmers used diverse strategies to reduce their crop loss to wildlife, including moving periodically (Crosby 1986), guarding their fields, hunting, planting fields in scattered locations, intercropping, and rotating crops with fallow (Goldman 1986). The dominant approach to pest management in modern, industrial agriculture is the use of chemical pesticides to eradicate pest populations (but see Gliessman, 1990; Letourneau, 1990, for alternative examples). Within the vast literature on modern pest management, rodents and invertebrates receive the greatest

attention due to their ubiquitous, and significant damage to agricultural production.

Crop damage by medium to large-bodied mammals (>3 kg) merits special treatment. These mammals have a unique relationship with humans. As potential game animals, many are valued as a source of protein (Robinson and Redford 1991). Some large animals are revered as religious symbols (Mohnot 1971; Sukumar 1994; Ville 1995), while others are feared as a threat to human life and property (Crosby 1986; Harrison 1992). Whatever the economic, social or psychological significance of medium to large mammals, their survival is at risk today. If a crop pest is an endangered or threatened species, simple eradication is not an appropriate management strategy.

Traditionally, subsistence farmers have attempted to balance crop loss to large mammalian 'pests' with gains by hunting or trapping animals which visit their fields (Marks 1976; Caldecott 1988; Vansina 1990; Dove 1993). So valued are the animals as game that certain crops are said to be planted to attract animals to gardens (Clay 1988). Human ecologists hypothesize that in garden hunting systems, the biomass of game animals may increase or their geographic range expand due to the dietary supplement of crops (Linares 1976; Bahuchet and Garine 1990). This reciprocal adaptation between humans and wildlife is thought to be ancient in Africa (Bahuchet and Garine 1990).

Garden hunting may be impractical where large and dangerous animals are abundant. At some sites, heavy losses of property and human life to wild animals may force farmers to abandon agriculture all together (Osmaston 1959; Graham 1973; Barnes 1990). Such was the case in much of pre-colonial Uganda and forested Africa when animal depredation on crops, especially by elephants (*Loxodonta africana*), made much potentially arable land uninhabitable (Graham

1973; Crosby 1986; Booth et al. 1992; Ville 1995). In fact, elephants are not mentioned in the garden hunting literature.

Garden hunting systems are characterized by communal ownership of wildlife. Where farmers are prohibited from utilizing wildlife, they will not legally be able to balance crop loss with hunting benefits. Throughout history, agriculturalists neighboring royal hunting reserves have been forced to suffer crop and livestock losses to royal game without remuneration. Ancient Syrian farmers could not hunt the King's lions though the lions preyed upon their livestock (Graham 1973). Likewise, farmers attempting to grow crops adjacent to Sherwood Forest were forced to accept damage by the red deer belonging to King Charles II (Graham 1973). A North American farmer in the 18th century fared no better if his farm lay

> contiguous to the estate of some surly Squire and the scanty crops which his industry has raised, be exposed to the daily depredations of the Squire's Game without the remotest prospect of indemnity. An individual, thus situated, is precluded firing a shot even on <u>his own land</u>, and at the very animals which have committed a <u>trespass</u> for the purpose of destroying his crops. (Long, in Lund 1980:117, emphasis in original)

For most of the world today, the risk of losing life or property to large wild animals is negligible. The conversion of vast areas of natural habitat during the past three centuries has drastically reduced the number and distribution of large mammals (Peters and Lovejoy 1990). Where wildlife persists, it is most often relegated to protected areas and legally defined as state property. As agriculture and wildlife habitat become spatially segregated, likewise hunting and farming decouple. Wildlife, especially large animals, are unlikely to fit neatly into the legally defined spatial compartments of a crowded human landscape (Naughton-Treves and Sanderson 1995). In other words, the

boundary of a national park is unlikely to be congruent with the real edges of biotic or socioeconomic systems (Newmark 1985). This zone of incongruence is where human-wildlife conflict is likely to be greatest (Smith et al. 1990).

Wildlife-human conflicts are most acute where densely settled agriculture abuts a national park or reserve (Graham 1973; Moe et al. 1989; Newmark and Leonard 1991). As arable land becomes scarce, farmers lose flexibility in their decisions about locations for planting, and fallow cycles become abbreviated (Rocheleau, in prep.). The arena of coping strategies for the local farmer is circumscribed on one hand by the legal protected status of wildlife and corollary hunting restrictions, and on the other by a lack of options on where, what and when to plant. Under these confined conditions, the relationship between humans and wildlife changes.

Wildlife confined to protected areas likewise lose alternatives, as their historic migration routes are cut off and foraging areas reduced or eliminated (Brooks and Buss 1962). Where habitat loss is rapid and extensive, wildlife densities may become artificially elevated in the remaining protected areas (Leggat 1965; Graham 1973; Sukumar 1989). Wildlife communities residing in islands of natural habitat surrounded by agriculture face a drastically altered environment from that in which they evolved (Baldwin and Baldwin 1976). The composition of the wildlife community may shift as certain species are better able to adapt to altered or edge environment (Kavanagh 1980). Certain species, populations or even individual animals may become specialists on crops and exhibit altered ranging and social behavior due to access to highly nutritious cultivars (Maples et al. 1976; Sukumar 1989).

State institutions meanwhile bear an internally contradictory role as the legal owner and protector of wildlife, and the guarantor of civil society's right to

private property. Public intolerance to sharing a landscape with wildlife may be high, especially for species capable of physically harming humans. This intolerance is not confined to any particular culture or economic level, and may be fueled as much by perception of risk, as by actual losses (Voyles 1994). Public intolerance may lead individuals to kill endangered or rare species (Riccuiti 1995). In such cases, wildlife managers face the formidable problem of protecting free-ranging animals in a hostile landscape.

Searching for means to reduce human-wildlife conflict, some conservationists propose that certain land uses on the periphery of protected areas could serve as buffers between natural habitat and human settlements. Such 'buffer zones' are conceptualized as areas ranging from tens of meters to kilometers around core protected areas where "a harmonious relationship between the natural environment and people is promoted" (Brown et al. 1992:4). Low intensity resource use, such as agroforestry is typically prescribed in these areas (Van Orsdol 1987). The management goals of buffer zones more often highlight economic opportunities for local populations than they do enhancing wildlife habitat or controlling the extent of wildlife foraging activities (Brown et al. 1992). Despite their popularity in wildlife and park management literature, it is difficult to find functioning examples of buffer zones where wildlife conservation and local human resource use are balanced (Wells and Brandon 1992).

Beyond attempts to buffer the edges of national parks, managers at several sites in Southern and Eastern Africa, as well as Asia, have attempted to resolve wildlife-human conflicts by sharply delineating park boundaries with electric fences and trenches (Seidensticker 1984). These expensive management strategies may placate the local populace; however, confining wildlife to an

insular parcel of land contradicts basic principles of conservation biology (Wilcox 1980). Most parks and reserves are too small to support populations of large vertebrates, or to sustain ecological processes that generate and maintain high levels of biodiversity (Newmark 1985). Fences restrict migration routes with potentially lethal consequences for wildlife (Owens and Owens 1984). Similarly, social scientists vigorously criticize attempts to isolate parks from rural populations, and forecast doom for conservation programs that erect barriers between people and wildlife (Adams and McShane 1992).

Foreseeing the social and ecological limitations of parks, social scientists and conservation biologists alike call for a more holistic approach, where ecosystems are managed beyond the scale of a single park, and human resource use is incorporated in management strategies (Christensen et al. 1995; Perrings et al. 1995). Such concepts of large-scale, flexible, integrated land management are difficult to implement within political-economic contexts based on property boundaries and spatially segregated land use. To manage landscapes for both humans and wildlife, we will somehow need to reconcile local needs with larger scale concerns. While wildlife may be considered a national or global legacy, a narrow subset of citizens absorb the costs of conserving it. Animals that are cherished symbols of wilderness to a general population may be pests or vermin to local agriculturalists. Managing ecosystems which include large animals will require sophisticated land use planning, elevation of public tolerance for wildlife, and technical improvement in reducing human-wildlife conflict.

Case study at Kibale National Park, Uganda

The relationship between the wildlife of Kibale National Park, Uganda

and the surrounding agricultural population is an illuminating case study (Figure 1-1). Here the Toro people have a long history of coexistence with an assemblage of large mammals, including many species notorious for their foraging on crops, such as elephants, hippopotami (*Hippopotamus amphibius*), bushpigs (*Potamochoerus porcus*), and several types of primates (Else 1991; Estes 1991; Vercammen et al. 1993). These wildlife species restricted the agricultural production of Toro due to their depredations on crops and transmission of lethal zoonoses to livestock (e.g. trypanosomiasis) (Osmaston 1959; Graham 1973).

While Toro farmers and wildlife coexisted historically, their interactions at the edge of Kibale National Park are today ruled by a modern political and ecological context of land scarcity and property boundaries. During the past two centuries the physical landscape has been dramatically altered by the introduction of exotic crops, the immigration of new ethnic groups, rapid population growth, official wildlife eradication campaigns, and large scale deforestation (Brooks and Buss 1962; Hamilton 1984). Traditional Toro institutions of governance have also been transformed by their incorporation into national and international political structures and markets.

The physical and political upheaval in Uganda have caused precipitous declines in large mammal populations as they suffered heavy hunting pressure, both official (Graham 1973) and illegal (Malpas 1980), and rapid and extensive loss of habitat. For many species, Kibale National Park represents a last refuge in Uganda. The dynamics of human-wildlife relations in this context portend much for the threat facing large mammals in a crowded human landscape.

In this study I focus on the interactions between sedentary, small-scale farmers and medium to large mammals (>3 kg) on the edge of Kibale National Park to better understand human/wildlife relations in a densely settled

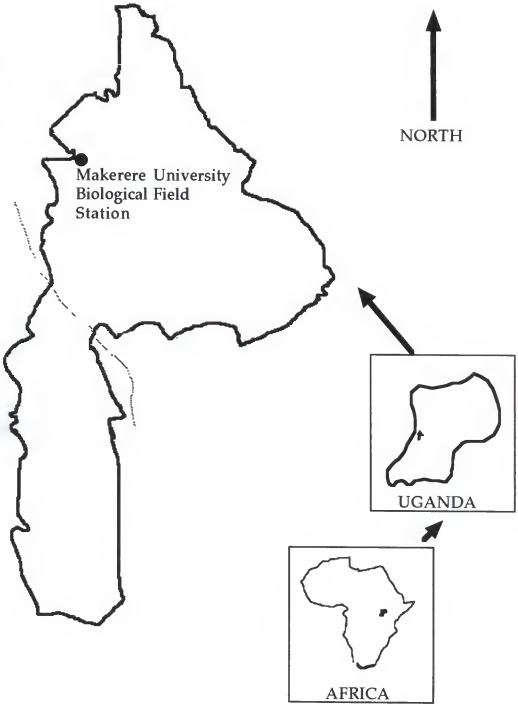


Figure 1-1. Kibale Forest National Park. Insets (counter-clockwise from bottom): Uganda in Africa. Kibale in Uganda.

landscape and modern property system. The specific research questions and results are organized as follows:

Chapter 2: To explain the significance of the current conflict between wildlife and humans at Kibale, I provide a brief overview of wildlife management in Uganda from the pre-colonial years to the present-day. The socio-political and ecological conditions in Uganda have gone through tremendous upheavel during the past 100 years. The relationship between humans and wildlife has been similarly dynamic. In the past, the coexistence of wildlife and farmers was possible within a setting of low human population density, extensive natural habitat, and communal ownership of wildlife which allowed farmers to hunt in their fields. For much of the 20th century, colonial game departments aimed to confine wildlife to parks and eradicate "vermin," including animals identified today as endangered, such as elephants and leopards. I demonstrate that human-wildlife interactions at the forest edge are now ruled by an ecological and political context of land scarcity, state ownership of wildlife, and compartmentalized land use which elevates the consequences of conflict for both farmers and wildlife.

Chapter 3: I first present data regarding the frequency, extent, and predictability of crop foraging by different species and identify crop preferences. This information reveals which animals are most capable of exploiting the forest-agriculture edge habitat. Then I test contextual variables, such as human population density, guarding, hunting and distance from the forest, as predictors of damage. This test is performed at two levels of analysis, the field and the village. This allows for an examination of how landscape features, shaped by individual and collective action, affect the extent of damage.

Chapter 4: I compare the complaints of "worst animals" by farmers with

systematically measured crop damage by wildlife and livestock in farms around Kibale. Perceptions of "most vulnerable crop" are compared to the monitoring data from Chapter 3. Beyond revealing concordance and discrepancies in complaints versus actual damage, I test how variables, such as ethnicity, sex, length of residence, employment, and affluence, influence the naming of worst animals and most vulnerable crop. I examine how these variables, as well as the incidence of crop loss to wildlife, shape local perceptions of the purpose and benefits of Kibale National Park. The importance of specific political conditions in amplifying local perceptions of vulnerability emerges when I examine the results of local discussions regarding life on the edge of Kibale.

Chapter 5: I present the temporal pattern of foraging on crops by five wildlife species (elephant, bushpig, redtail monkey, olive baboon and chimpanzee) at Kibale. I examine the frequency with which each species forages on crops, and compare the intermonth variability. Then I determine whether variation in the frequency of crop foraging correlates with rainfall and/or the availability and phenology of forest fruits. Results from these analyses demonstrate that the use of agricultural and natural food resources are strongly linked for several wildlife species.

Chapter 6: Drawing on the information of the previous chapters, as well as case studies from other sites in Africa and beyond, I present recommendations for the management of human-wildife conflict at Kibale National Park.

The clear depiction of wildlife-human relations at Kibale is meant to contribute to ongoing efforts to incorporate communities in conservation efforts, and to manage ecosystems for both wildlife and people beyond the level of a single park. Given that human-wildlife conflict is a relatively new, but

increasingly important, subject for conservation research, study methods are carefully presented and discussed throughout the chapters.

CHAPTER 2

CONTROLLING AND CONFINING WILD ANIMALS: A HISTORY OF UGANDAN WILDLIFE MANAGEMENT

Pre-Colonial Period

Kibale National Park is a 766 km^2 remnant of an extensive forest system that prior to the colonial period connected south to the forests of the Rwenzori Mountains and the Virungas (Osmaston 1959) and west to the Ituri forest of Zaire. It is a midaltitude rainforest, most famous for its exceptional diversity and density of nonhuman primates (Struhsaker 1981*a*). Kibale is also regarded as a possible Pleistocene forest refugium, as it contains Congo Basin species at the eastern extreme of their range (Struhsaker 1981*b*).

The ancient settlement history of the region around Kibale is not clearly documented. The fact that over 20% of Kibale is fire-maintained grassland combined with the abundance of pottery shards found in simple excavations suggests a longterm human presence (Osmaston 1959). The original inhabitants of forested Central Africa were presumably stone age hunter-gatherers living at extremely low densities close to rivers or savannah areas (Vansina 1990). Bantu farmers reached neighboring southeastern Zaire around 3000 B.P. (Vansina 1990), but evidence of the earliest settled agriculture in Uganda dates to around 2300-2200 B.P. (Phillipson cited in Hamilton 1984). For the next millennium, human settlement in western

Uganda and eastern Zaire was sparse and clustered within a matrix of forest (Vansina 1990).

Several factors led to the expansion of Bantu agriculturalists into forests. Most notable was the introduction of the banana (*Musa spp.*) to the region as early as 1700 B.P. (Vansina 1990). *Musa* is an ideal crop for evergreen forests. Compared to the autochthonous yams (*Dioscorea cayenensis*) or oil palms (*Elais guineensis*), bananas have a much higher yield, a longer planting season, require less labor input, less extensive forest clearing, and less food preparation time (Vansina 1990).

Whatever the exact date of *Musa* introduction to western Uganda, forest wildlife have been foraging on it for hundreds of years. In fact, early Bantu farmers in the region claimed *Musa* fallows were ideal for trapping game (Vansina 1990: 87). Sugar cane (*Saccharum officinarum*) was introduced from India during the same period (Vansina 1990) and has also become a favored forage for some species (this study).

Over the following centuries, farming and trapping remained closely linked for Bantu farmers living in the forest, such that "a yam field also produced bushpigs and beans produced antelopes" (Vansina 1990: 90). After 1600, crops from the Americas were introduced to African forests, including cassava (*Manihota esculenta*), groundnuts (*Arachis hypogaea*), beans (*Phaseolus vulgaris*), and maize (*Zea mays*). Cassava proved to be an ideal forest crop for reasons parallel to *Musa* (Vansina 1990: 214). Not surprisingly, cassava is also a preferred food for bushpigs (this study), as it is a widespread favorite of the superfamily Suoidea, e.g. the Neotropical Collared Peccary (*Tayassu tajacu*: Suarez 1993) and Southeast Asian Bearded Pig (*Sus barbatus*: Caldecott 1988).

Kibale National Park lies within Kabarole District, known formerly as Toro District, and, before the colonial period, as the Kingdom of Toro. The Toro people are part of an ethnic group located in the western Lake District and broadly defined as the Western Lacustrine Bantu (Steinhart 1971; Ingham 1978). This ecologically diverse region was historically inhabited by various cultures employing different land uses. Generally, the Bantu farmers inhabited the foothills and plains, while Pygmoid peoples inhabited the forests. The Toro people are not recognized to be a socially or politically, tightly cohesive group (Ingham 1978); rather, they have periodically unified in resistance to the advances of larger neighboring kingdoms. The Toro people share an official Bantu language (rutoro) but have varied ethnic origins and land use systems.

The Toro people were twice invaded and conquered by pastoralists, first in the 15th century by the Bacwezi of Bantu origin (Ingham 1978), and later by the Babito of Nilotic origin (Steinhart 1971). The immigrant pastoralists were in the minority (5-10%) but held political power over the majority resident agriculturalists (Ingham 1978). The Toro Kingdom twice briefly emerged as an offshoot of the neighboring Bunyoro Kingdom during the late 19th and early 20th centuries.

Throughout the history of Toro, kings with centralized power ruled over chiefdoms. The land tenure system was akin to feudalism as royalty owned large properties, including hunting reserves, and agriculturalists paid tribute in crops (Taylor 1962). At the end of the 19th century, the Toro people were settled in small (approximately 40 households), isolated, predominantly agricultural communities, each identified with a clan (Taylor 1962).

Historical descriptions of the Toro people offer minimal information on their relationship with wildlife. Some sources describe a royal hunting reserve in the southern reaches of what is defined today as Kibale National Park (Aluma et al. 1989). Traditional hunting norms were set by Toro custom which dictated that meat from a kill was distributed first to the man spotting the animal, then to the first 3 men to spear it, and then to the chief of the area on which it was killed (Taylor 1962). In comparison to neighboring tribes, however, the Toro "are not great hunters" (Osmaston 1959:39). Toro culture traditionally included belief and practice in propitiation of animal spirits, "especially those of the larger, more dangerous and otherwise awe-inspiring animals killed in the hunt" (Taylor 1962:63), however by the 1950s, most Toro were "unconcerned with animal spirits" (Taylor 1962:65).

In 1878, Stanley described Western Uganda as a "field and harvest ripe for the sickle of civilization" (Steinhart 1971:3). The subsequent colonial harvest consumed the Toro Kingdom. By eliminating royalty, colonialism released Toro people from the domination of other kingdoms, but left them with only very weak identification with colonial institutions such as the church or nation-state (Taylor 1962:67). The physical transformation of Western Uganda was perhaps even more permanent and merits treatment within a national context.

Deforestation during the Colonial and Postcolonial Era

During the past 200 years, Uganda suffered extensive deforestation, particularly during the past half-century (Leggat 1965; Hamilton 1984). Uganda's forests were primarily lost to agriculture. Deforestation rates have

mirrored the rapid expansion of agricultural land. In one decade alone, the area under crops increased 18.3% (World Resources Institute 1994:12). In the absence of human disturbance, approximately 20% of Uganda would hypothetically be under closed canopy forest (Hamilton 1984). In 1900, 12.7% of Uganda was forested. By 1958, forest cover had been reduced to 4.6% (Hamilton 1984). Through the 1970s and 1980s, 65,000 ha of forest were lost annually, leaving only 2 to 3% of Uganda under closed canopy forest by 1990 (Struhsaker 1987; Howard 1991). The loss of Uganda's moist forest has been particularly severe, estimated at 86% reduction of its original extent (World Resources Institute 1994).

The deforestation history of the Toro District (today officially renamed Kabarole District) parallels national trends in the conversion of forest to agriculture. Human population in Toro grew by 34.2% during the 1950s (Leggat 1965), and more than tripled between 1959 and 1991, outpacing the national annual growth rate (>7% vs. 3%: WorldBank 1993). This rapid growth is due in part to the arrival of Bakiga immigrants from the densely populated Kigezi District, 200 km to the southwest. These immigrants were mobilized by official resettlement schemes during the mid-1940s, and by wage employment opportunities at tea plantations in Toro. The tea plantations were established at the cost of extensive tracts of forest (Kluge, S. pers. comm.) and tea processing factories drew heavily on fuelwood supplies.

Colonial Government Assumes Control of Forest and Wildlife Resources

Local forest management was supplanted by the Toro Agreement of 1900 in which

> all the waste and uncultivated land which is waste and uncultivated at the time of this agreement, (and) all forests...shall be considered to be the property of Her Majesty's Government, the revenue therefrom being included within the general revenue of the Uganda Protectorate. (Osmaston 1959:16)

Formal reservation and demarcation of Crown Forests (including Kibale) did not occur until thirty-two years later, during which time much of the forests were lost to agricultural encroachment (Howard 1991:12).

In the case of Kibale, the advance of the agricultural frontier into the forest at the beginning of this century was halted and even reversed by local conditions, including an abundance of wildlife. The Assistant Conservator of Forests wrote in 1959 that

> owing to the small population, the abundance of land, and the depredations of game . . . this [delay in demarcation] has fortunately not resulted in any loss to these forests. (Osmaston 1959:16)

In fact, during the 50 years prior to Kibale's demarcation, a localized expansion of the forest was observed. This resulted from the reduction of human and cattle populations by war and rinderpest which started a move away from the forest, stimulated further by "the depredations of game that the few remaining inhabitants were no longer able to repel" (Osmaston 1959:15). When Kibale was finally demarcated as a Central Forest Reserve in 1948, an era of mechanized logging began (Osmaston 1959). A sawmill was established in northern Kibale at Sebitoli and by 1950, hardwoods were extracted in steadily increasing volumes (Kingston 1967). Over the next 35 years, 74 km^2 of Kibale were disturbed by mechanized logging (Skorupa 1988; Howard 1991).

The stated management objective for Kibale was the maximum sustained harvest of hardwood timber from the natural forests, and the maximum economic production of timber from exotic plantations established in the grasslands (Kingston 1967). The preservation of suitable areas as nature reserves was only a secondary goal.

> At present little use or study is made of the game, though in the future the forests are likely to be of increasing importance as a retreat for game of all sorts. (Osmaston 1959:39)

The Forest Department allowed local harvest of wild coffee and fuelwood and pole collection; however,

> the forest is at present of little importance in providing building poles and fuel to neighboring peasants as most of them have small areas of forest or bush nearer at hand. (Osmaston 1959:22)

The recent depletion of forest patches neighboring Kibale has led to increasing pressure on the forest within the Park for poles and fuelwood (Kaipiriri in prep.).

References to Kibale's wildlife in early management reports emphasize the damage elephants cause to regenerating forest and plantations (Osmaston 1959; Leggat 1965). Heavy hunting pressure and habitat loss forced regional populations of elephants to retreat to Kibale Forest such that, by 1956, the population density was over 2,000 elephants (Osmaston 1959; Brooks and Buss 1962). The conflict with elephants and forest management was serious enough that a forest officer declared "No silvicultural work can . . . be undertaken profitably until the elephants are to some extent controlled" (Osmaston 1959:31). In the northern section of the forest where logging was heavy, "repeated visits by elephants have caused most of it to remain in or

revert to the tangle stage" (Osmaston 1959:25). A goal was set to exclude elephants from regenerating forests and plantations and to reduce their numbers but otherwise "to interfere as little as possible with the elephants provided these requirements are met" (Osmaston 1959:25). Patrolling and shooting were identified as the only means of protection available and a plan was laid to "pursue any elephants that have entered the Reserve (regeneration areas), attempting to shoot at least one of each herd and to hustle the others away" (Osmaston 1959:App. 19). Limited experiments with electric fencing were attempted with minimal success (Kingston 1967). A National Forest Officer formally commented that "the Forest Department could ill afford to allow for a reduction in output of timber to provide amenities for big game in forest reserves" (Leggat 1965), and more to the point wrote in internal department correspondence:

> I can only hope that it will be realized by all concerned that the only place for elephants are the National Parks, and elsewhere they must be eradicated as pests. (Leggat 1956)

During the colonial period and immediately thereafter, the Ugandan Forest Department exhibited the "hallmark characteristics of an African forestry department" (Little and Brokensha 1987:202). Commercial forestry and plantations of exotic tree species were the management priorities. There was minimal interest in local people's usufruct rights or ethnobotanical knowledge, rather the Forest Department served to police local use. The move to centralize forest management paralleled a national trend toward topdown, blueprint management that, ideally, was meant to ensure efficiency and rationality in the management of resources. However, the policy established during the colonial period served to alienate rural populations

from forest management by removing a large area of forested land from local, traditional authorities.

Development and Conservation around Kibale after 1950

Outside Kibale's boundaries, land pressure increased as the growing resident Bakiga population became a magnet for further settlers, and second generation immigrants required more arable land (Aluma et al. 1989). Toro chiefs allocated land for the immigrants to the south of the Forest Reserve in the "royal hunting area" (Aluma et al. 1989), officially known as the Kibale Game Corridor Reserve which connects Kibale with Queen Elizabeth National Park (Figure 2-1). In a chronicle of Bakiga history, it is reported that

> many Batoro felt that Bakiga settlement on the outskirts of their own settled agricultural area would serve as a buffer from crop damage by wildlife. (Kabera in Aluma et al. 1989:27)

The allocation of land to the Bakiga in the Game Corridor was not challenged at the time by government officials (Aluma et al. 1989). By 1970, all Game Corridor land had been allocated and Bakiga settlers began establishing farms inside the western boundary of the Forest Reserve (Aluma et al. 1989).

Although Kibale suffered increasing encroachment, its prospects for conservation improved in 1970 when a biological field station was established at Kanyawara by the New York Zoological Society (NYZS) (Figure 2-1).

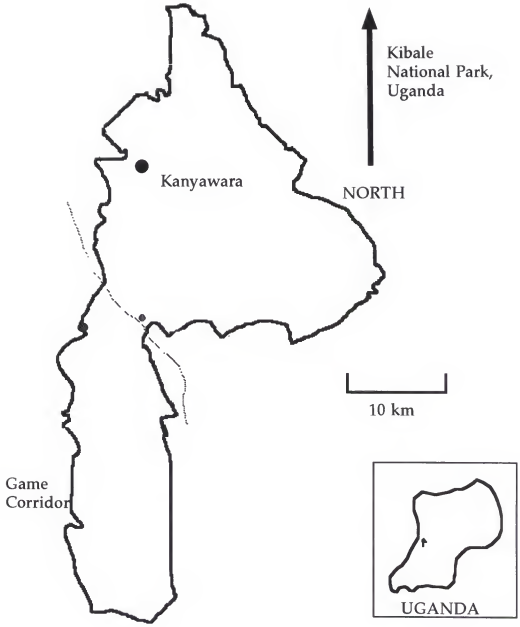


Figure 2-1. Kibale National Park and the Game Corridor.

Through the research and advocacy of Ugandan and international scientists, the exceptional fauna of Kibale began to receive international recognition (Waser 1974; Struhsaker 1975; Struhsaker and Oates 1975). Further elevating the conservation importance of Kibale was its connection to neighboring protected areas in the savannah ecosystem to the southeast, specifically to Queen Elizabeth National Park (Howard 1991). The size of Kibale and its connection to protected savannah habitat allowed for the presence of large and rare animals, such as elephants, buffalo, chimpanzees and leopards. By 1970, Kibale represented one of the last substantial tracts of midaltitude forest in Uganda (Howard 1991).

Between 1971 and 1986, Uganda suffered war, severe economic recession and the disintegration of the state (Rothchild and Chazan 1988). Amidst the collapse of the public realm, individuals sought to evade political authority rather than attempt to participate in civil society (Hyden and Bratton 1992). Not surprisingly, the Forest Department lost control of much of the reserves due to a precipitous decline in funding, low employee morale, and public disregard for governmental authority (Hamilton 1984). Poaching ravaged the nation's wildlife. Between 1970 and 1980, Uganda's elephant population plunged from 30,000 to 2,000 (Malpas 1980). Cheetah (*Acinonyx jubatus*) and rhinoceros (*Diceros bicornis*) were driven extinct. Encroachment in parks and reserves accelerated, partly due to ex-President Idi Amin's announcement that Ugandans were free to settle on any unoccupied land (Hamilton 1984). By the war's end, 3,000-5,000 people were illegally residing within Kibale Forest Reserve, while upwards of 50,000 farmers inhabited the Game Corridor (Aluma et al. 1989). Approximately 70 km^2 (16%) of Kibale's forest were lost to severe encroachment (Howard 1991).

With peace in 1986, conservation efforts redoubled at Kibale. Tourists began visiting the forest. International conservation organizations (Wildlife Conservation Society-NYZS) and development agencies (European Community, United States Assistance for International Development (USAID)) increased their investment in Kibale to over US$1 million per year. Responding to pressure from national and international conservationists and recognizing the tourism potential of Kibale, the Uganda government evicted encroachers from the Reserve and the Game Corridor in 1992, and in 1994 elevated Kibale Forest to national park status.

Recent efforts to fortify the protection and management of Kibale National Park have included greater attention to the concerns of the local populace. The main objectives of community outreach work during the past decade were to improve soil management and promote greater appreciation of the conservation importance of Kibale. Participation in community programs was primarily restricted to residents within a 10 km radius of Kanyawara (Nganzi 1994). In an independent, parkwide survey of local attitudes toward Kibale Forest, crop raiding by wildlife emerged as the most frequently mentioned issue of concern (Edmunds 1994).

Managers responded by promoting research on the problem (e.g., this study), planting trial plots of less palatable species at the forest edge, and promoting the establishment of a buffer zone around the forest. Despite official goals of reducing wildlife/human conflicts and providing farmers with access to forest products, to date the buffer zone remains a poorly defined concept, subject to confusion regarding its size, position relative to the Park boundary, and user rights. To make the buffer zone functional, it will be necessary to define more precisely the purpose and the location of the zone,

and the community it is meant to serve. Missing in the debate over the buffer zone is information on the spatial and temporal distribution of wildlife foraging on crops and how farmers respond. This study intends to address these questions. To understand the significance of the human-wildlife conflict at Kibale, it is first necessary to briefly review official management policy concerning Uganda's wildlife.

Wildlife Control and Eradication during the Colonial and Postcolonial Era

In 1906, the government of the Protectorate of Uganda enacted the Cattle, Game, Animals, and Ostriches Ordinance, based on game laws of Kenya which were in turn derived from medieval English legislation (Graham 1973). Centermost to the game laws was the royal prerogative claiming all Ugandan game animals as automatic property of the Crown. Local citizens could hunt only nontrophy animals and only with permission from the government. Rules regarding hunting techniques were also legislated. Trapping game was prohibited as colonial authorities considered it cruel. Integral to formal game legislation was the classification of wildlife species as Great Game Animals, Game Animals and Vermin (Graham 1973). Likewise sport hunting and vermin extermination were distinguished by the class of animal killed (Graham 1973:144). Great Game Animals included elephants, rhinoceros and giraffes (*Giraffa camelopardalis*) and could only be killed by high caliber rifles. The coveted and lucrative horn and ivory trade may have been behind these restrictions (Graham 1973:60). The seemingly arbitrary list of Game Animals included several antelope species, game birds, vultures, and trout (Graham 1973):68). At the other extreme were Vermin,

such as lions (*Panthera leo*), leopards (*P. pardus*), hyenas (*Crocuta crocuta*) and "ubiquitous pests such as bushpigs and baboons, devoid of trophy and nobility and simply scum" (Graham 1973:68). Vermin were not subject to humane killing laws and were poisoned or trapped (Graham 1973).

Crop loss to wildlife in Uganda was formally recognized as a problem deserving government intervention in 1924 when the Elephant Control Department was established (Graham 1973). The next year it was renamed the Game Department and assigned the conflicting mission of (1) preserving hunting stocks for the elite and (2) controlling crop damage by game. Compared to neighboring Kenya, wildlife-human conflicts were more intense in Uganda due to the higher proportion of agriculturalists versus pastoralists (Graham 1973). The Uganda Game Department resembled a miniature army: half the wardens were military men and its actions over the next 20 years were described as a "pogrom of Uganda's elephants" (Graham 1973). During forty-five years of "control operations" between 1925 and 1969, the Game Department killed an average of 1,000 elephants a year for a total of 31,966; an additional 8,170 were killed by licensed hunters (Brooks and Buss 1962). Adding estimates from illegal hunting, approximately 150,000-200,000 elephants were killed in Uganda between 1900-1970 (Graham 1973:115).

Leopards, lions, buffalo (*Syncerus caffer*), crocodiles (*Crocodylus spp.*) and other 'vermin' were similarly 'controlled'. Thousands of crocodiles were shot or poisoned, and their eggs destroyed in a national eradication campaign (Graham 1973:111). Once a verminous species was severely depleted, its status typically changed. Thus, lions became game animals in the 1920s, as did leopards in 1933, and cheetahs in 1954 (Graham 1973). However, their new status did not offer protection. Leopard extermination reached a peak of 2,388

in 1945 and was celebrated for "the definite benefit in reducing depredations [on livestock]" (Graham 1973:71). Rhinoceros were also 'controlled,' despite their status as Great Game. Over 1000 were killed by a hunter hired by the Game Department in 1943 (Graham 1973:71).

Elephant control operations were implemented chiefly at agricultural frontiers (Brooks and Buss 1962). Once exterminated, land was cleared and crops planted (Graham 1973). Where elephants swarmed in 1920, they are now absent (e.g. Mubende, Graham 1973:105). In 1924 elephants ranged over 75% of Uganda. By 1970, less than 13% of Uganda was inhabited by elephants (Graham 1973:95). Where elephants persisted, they were compressed into smaller areas leading to increased densities and conflicts with humans (Leggat 1965).

Despite the carnage, throughout the first 25 years, Game Department officials argued that they were barely keeping up with population control (Ritchie in Graham 1973). It was not until after 1950 that the Game Department sounded the alarm on declining populations, and named poaching as the problem. Yet the department continued in its control measures wherever human lives and property were at risk. In neighboring Kenya, a game warden reported public tolerance of wildlife crop damage was lowest in the densely populated and more affluent highlands (Graham 1973). In some instances, Kenyan farmers were also reported to have imitated elephant damage to their own crops so that game wardens would come, shoot an elephant, and give the community the meat (Graham 1973). The contradictory mission of Ugandan and Kenyan game departments to protect and exterminate wildlife was embodied by the gamekeepers' task:

> the lives of gamekeepers are wholly spent in the netherland of boundaries that always comes into being when two opposing forces meet. Their waking lives are spent darting about between the animals and the humans, across the no man's land between them. One day the humans are being warded off from the animals; the next day is spent separating the animals from the humans. (Graham 1973:104)

Regional Records of Wildlife Control Programs

Three western districts, Toro, Bunyoro, Mubende-Mengo, were the site of two-thirds of the elephant killings recorded between 1927 and 1958 in Uganda (Brooks and Buss 1962). Yet in 1962, the Chief Game Warden of Toro still complained that "elephant numbers are so high that we can't deal with anything else" (Records of Western District Office of the Game Department 1950-1992).

The Office of the Game Department for the Western District maintained records regarding control programs and also filed letters of complaint from local citizens regarding wildlife. While the records are neither complete nor systematic, they provide information regarding which species were the focus of control campaigns over the decades, and where human conflicts with wildlife occurred in the region.

Between 1950 and 1971, the Game Department killed elephants (113), buffaloes (33), hippopotami (11), lions (3) and leopards (2) in the Western District control campaign. The control records for sites >10 km from Kibale Forest are noteworthy in that many of the problem animals listed during the 1950s and 1960s are locally absent today (e.g. buffalo at Rweihamba village, or lions 7 km outside of Fort Portal). The records for sites near Kibale Forest reveal that elephants have been raiding crops at certain sites for over 40 years,

and continue to do so (e.g. Sebitoli and Rurama, this study). Also recorded during this period was human conflict with buffalo and hippopotami on the forest perimeter. Currently, at these sites no problems are registered with these animals due to minimal or nonexistent local populations.

During the years of political turbulence (1972-1985), there was a shift in the species targeted for control activities. Cane rats (*Thryonomys swinderianus*: >5000), bushpigs (1172), monkeys (560), baboons (*Papio cynocephalus anubis*: 507), porcupines (*Hystrix africae-australis*: 323), civets (*Civettictis civetta*:120), buffalo (36), elephants (36), hippopotami (18), and chimpanzees (*Pan troglodytes:* 13). Finally, from 1986-1992, records available indicate that baboons (106), monkeys (85), bushpigs (10), and civets (1) were killed in control programs. Many of these animals were killed in 'self-help' or 'tribal' hunting programs in which the Game Department authorized community-based 'vermin control.' While the Provincial Game Warden termed these programs a 'great success' (59 bushpigs killed in one parish), he noted that local residents were selling bushpig meat and that he hoped that bushpigs would not be killed where they did not destroy crops.

The records also indicate confusion over the status of certain animals listed under Game Control during one year, and Vermin Eradication during another. For example, during the early 1970s, chimpanzees were listed targets for vermin control. Then in 1975 the Chief Game Warden of the Western District announced that

> the chimpanzee is not a vermin and the chiefs should be informed about this. I note that tribal huntings were organised. Were these huntings supervised by Game Guards to ensure that only vermin fell victim?. (records from the Ugandan Department of Game)

From these records it is apparent that over a forty year period, conflicts with large wildlife species have been registered with diminishing frequency, and in a reduced geographic range that converges on the boundaries of protected areas. In recent years, complaints regarding baboons, bushpigs and monkeys overwhelm those about elephants, buffaloes and large felids.

Conclusions

Today over 89% of Ugandan citizens reside in rural areas, an extraordinarily high percentage even in the African context (WorldBank 1993). As this rural population grows at 3% per year, its demands for land, fuelwood, charcoal and timber further deplete forest resources (World Resources Institute 1994):16). The forest and wildlife habitat remaining in Uganda is almost entirely located inside reserves and parks (Struhsaker 1987). Currently 7.9% of Uganda is under Protected Area Status (IUCN Category I-V: World Resources Institute 1994:4). Even within these areas, 12% of forest has been lost to agricultural encroachment (Howard 1991).

Reflecting the national trend, Western Uganda is in the final stages of a transformation from a matrix of forest with islands of human settlement to the reverse: forest islands amidst a sea of agriculture. Colonial and post-Independence state institutions have attempted to separate agriculture and wildlife habitat spatially, via eradication of wildlife outside of protected areas and prohibition of human settlement within protected areas. Thus the human-wildlife conflicts historically present at agricultural frontiers are now confined to the boundaries of protected areas. Currently, the possible balance between crop loss and hunting gains has been destroyed with the prohibition

of local hunting and the drastic reduction in wildlife habitat. The dynamics of human-wildlife relations in this context portend much for efforts elsewhere to conserve large animals in a crowded human landscape.

CHAPTER 3

PREDICTING PATTERNS OF CROP DAMAGE BY WILDLIFE AROUND KIBALE NATIONAL PARK, UGANDA

Introduction

Permeable boundaries allow two-way traffic of wildlife and humans in and out of national parks. Wildlife species move across park boundaries to hunt or forage in neighboring habitat, while people enter parks to extract protected biota. Recognizing that park ecosystems are profoundly affected by human and natural forces which transcend and predate legal boundaries, many conservationists attempt to influence land use around parks. The integration of conservation with other land uses is especially difficult where densely settled agriculture abuts a protected area containing large or potentially dangerous animals, as is the case for several parks in Africa and Asia (Dudley et al. 1992; Sukumar 1995). While agricultural crops may provision wildlife species confined to meager patches of protected natural habitat (Milton and Binney 1980; Ganzhorn and Abraham 1991), local farmers are unlikely to tolerate crop loss without complaint. At sites where the risk of property damage and loss of life by wildlife is perceived to be significant, local communities may be hostile to wildlife and oppose conservation programs. The complaints of neighboring communities have led park managers to invest millions of dollars in strategies designed to prevent animals from leaving parks, such as constructing trenches and electric fences (Seidensticker

1984), or planting nonpalatable, dense crops, such as tea, around parks (Kanuhi 1995). Aside from the expense of constructing and maintaining such barriers, these efforts increase insular conditions of parks, and thus run counter to the mandates of conservation biology.

While the bitter complaints of farmers capture the attention of protected area managers, only rarely is the actual impact of different wildlife species measured, or factors tested to predict damage (Newmark 1995). The absence of this information hinders effective on site management, accurate comparisons between sites, and appropriate policy formulation. Given the politically volatile nature of human–wildlife conflict (anonymous 1994; Voyles 1994), and the high cost of current management options, there is an urgent need for careful analysis of field data. Moreover, if local communities are to take an active role in managing wildlife, it is important to understand how much crop loss is caused by various species, and how this loss is distributed within the farming community.

In this paper, I quantify the pattern of crop loss to wildlife around Kibale National Park, Uganda, where a diverse assemblage of animals forage on subsistence and cash crops. Independent surveys of environmental attitudes around Kibale, identified crop raiding as a dominant concern among local residents (Aluma et al. 1989; Forbes 1991; Kaipiriri in prep.). I first present data regarding the frequency, extent and predictability of crop loss, and crop preferences of different species. This information reveals which animals are best able to exploit the forest-agriculture edge habitat. Using multivariate methods, I test several social and physical variables as predictors of damage. Human population density, guarding, hunting, sight distance and distance from the forest are incorporated at two levels of analysis, the field and the village. These

analyses determine how landscape features, shaped by individual and collective action, interact to affect the extent of damage.

The results are meant to provide the basis for management efforts to reduce crop loss to wildlife, and to allow for a better understanding of local attitudes toward wildlife. Finally, a careful presentation and discussion of methods is offered, given that research on human-wildlife conflict is a relatively new, but increasingly relevant subject for conservation biologists (Else 1991; Dudley et al. 1992; Dublin 1995).

Background

Vertebrate 'pests' significantly reduce agricultural production on an international scale (Halverson and Crabb 1994). A correspondingly vast set of technical reports recommend how to eradicate problem species (typically rodents and birds) in industrial-scale monocultures (Hygnstrom et al. 1994). However, when the 'pest' happens to be an endangered species, and the farmers losing crops are individuals narrowly surviving on marginal lands, a different management approach is necessary.

Management-oriented research has tested the efficacy of fences, trenches, repellents, noise makers, and many other devices designed to discourage animals from foraging on crops (Seidensticker 1984; Osborn 1993). Such devices (fences in particular) have proven expensive to construct and maintain, and typically only partially inhibit the foraging of megafauna, while smaller animals are not affected (Milton and Binney 1980; Bell 1987).

Additional research on human-wildlife conflict has identified two categories of crop raiding animals: refuge-seeking animals which make forays

into fields from large islands of natural habitat (e.g., lemurs or elephants), and animals able to survive in small patches of natural habitat amidst agricultural landscapes (e.g., baboons or bushpigs: Bell 1984*a*; Ganzhorn and Abraham 1991). This is a simplified version of models of mammal communities at the forest-savanna edge which describe a continuum of dependence on the forest (Medellin and Redford 1992). Other ecologists argue more explicitly that certain species thrive in forest-agriculture edge habitat, out-competing forest species (e.g., vervets, *Cercopithecus aethiops*, (Kavanagh 1980). Behavioral ecologists, meanwhile, describe crop raiding as a high risk, high gain strategy (Greenhood 1971; Mohnot 1971; Sukumar 1989; Else 1991) motivated by insufficient wild forage (Sukumar 1995) and/or the advantages of nutritious cultivars.

Most of the recent published research on crop damage by wildlife around protected areas is based entirely on interviews with farmers (Hawkes 1991; Hill 1993; Newmark 1995). Such studies offer valuable insight, particularly into human perception of risk of crop loss. However, relying entirely on interviews introduces inaccuracies. At several sites, investigations have revealed disparity between reported and observed damage, with farmers most often overestimating the amount of crops lost to wildlife (Wakely and Mitchell 1981; Mwathe 1992; Reuling et al. 1992). Other studies of crop damage to wildlife introduce error into their conclusions when they extrapolate observations from a single site to describe conditions for an entire park or reserve. Due to the fact that such research frequently focuses on sites where crop raiding is most intense, damage may again be overestimated (Bell 1984*a*). Considering the potential cost of management options and the importance of the subject to local communities, crop loss to wildlife merits careful field measurement and an understanding of variability.

Study Area

Kibale National Park (Figure 3-1) is a 766 km^2 remnant of a forest system that prior to the colonial period extended south to the Rwenzori Mountains and the Virungas, and west to Zaire (Osmaston 1959). Amidst this vast forest wildlife and humans coexisted. Communal ownership of wildlife allowed farmers to hunt in their fields, thereby hypothetically mitigating the costs of crop loss (Vansina 1990). Nonetheless, crop damage by wildlife, particularly by elephants, made some of western Uganda's arable land uninhabitable (Osmaston 1959; Vansina 1990). During much of this century, colonial game departments aimed to confine wildlife to parks and elsewhere eradicate problem animals, such as elephants, hippopotami, and leopards, allowing the agricultural frontier to expand (Graham 1973).

The expansion of agricultural land was closely correlated with human population growth. For example, between 1959 and 1991, Kabarole District increased from 27 to 97 people per km^2 (World Bank 1993). The resulting land scarcity reduced flexibility in agricultural strategies and left Kibale as one of the last refuges for wildlife. Under these conditions, the costs of human-wildlife conflict are elevated for both wildlife and farmers neighboring the Park.

Today conservationists celebrate Kibale for its exceptional diversity and density of primates (Struhsaker 1981*a*), and regard it as a possible Pleistocene forest refugium as it contains Congo Basin species at the eastern extreme of their range (Struhsaker 1981*b*). Edge habitat is abundant at Kibale due to previous logging and agricultural activities within the Park. Today ~20% of Kibale is under fire-maintained grassland (Howard 1991). The mosaic of tall canopy forest, disturbed forest, agricultural fallows and grassland provides optimal

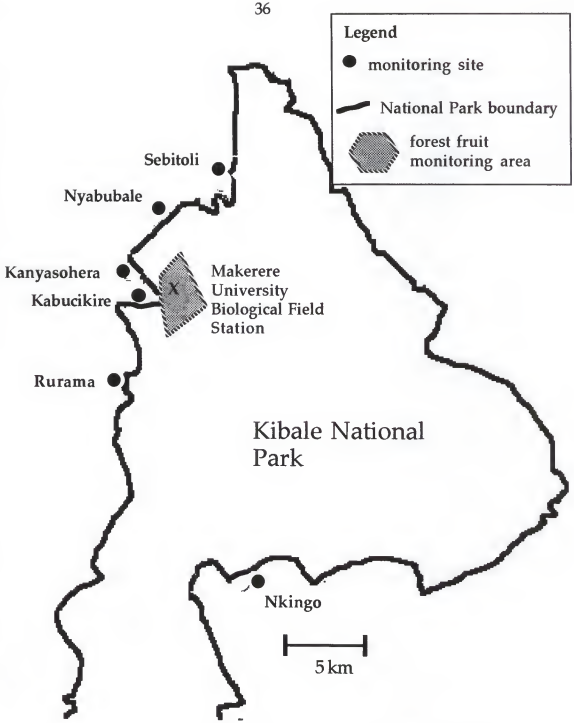


Figure 3-1. Locations of Study on Crop Loss to Wildlife at Kibale National Park (KNP), Uganda.

habitat for wildlife species able to exploit the forest–savannah edge (Butynski pers. comm.; Kavanagh 1980).

Among the assemblage of wildlife species present at Kibale are certain species notorious for their crop damage elsewhere in Africa. The diverse community of primates includes species belonging to two genera which are characteristic inhabitants of forest edge environments and farmlands adjacent to natural habitat: olive baboons (*Papio cynocephalus anubis*), as well as redtail, vervet, blue, and the endangered L'hoesti monkeys (*Cercopithecus ascanius, C. aethiops, C. mitis* and *C. lhoesti*) (Kavanagh 1980; Else 1991; Thomas 1991). The elephant (*Loxodonta africana*) population of Kibale has a long history of damaging timber stock, nurseries and crops in the surrounding area (Osmaston 1959). Also present are bushpigs (*Potamochoerus porcus*) and crested porcupines (*Hystrix africae-australis*): two poorly studied animals recognized as significant crop raiders elsewhere in Africa (Goldman 1986; Hill 1993; Vercammen et al. 1993; Lahm 1994).

Information regarding the distribution and density of these species throughout Kibale is incomplete. The spatial heterogeneity of the forest derives from climatic, edaphic, and disturbance factors, and the distribution of large vertebrates appears to be similarly patchy (Chapman et. al, in prep.; Wing & Buss 1970). Previous research at Kibale has compared wildlife species densities with forest disturbance levels (e.g., elephants prefer selectively felled areas; (Nummelin 1990; Struhsaker in press). Census data indicate that densities of primates vary significantly between sites within Kibale (Struhsaker 1981*c*; Skorupa 1988), but only one long term, detailed study addresses the causes of such variation (Butynski 1990). Considering the permeability of Kibale's boundaries, both in terms of illegal hunting within the forest and crop foraging

by wildlife in surrounding fields, wildlife population distributions may also be affected by human forces originating outside the forest.

Beyond Kibale's boundaries, forest has been largely converted to agriculture, due in part to a more than tripling of the region's human population in the past three decades (World Bank 1993). Currently, 58% of land within 1.5 km of the park boundary is used in smallholder agriculture (Mugisha 1994).

Agriculturalists in the area belong to two predominant tribes, the indigenous Batoro, and the immigrant Bakiga who began arriving in the area during the 1950s (Turyahikayo-Rugyema 1974). Both groups cultivate a mix of subsistence and cash crops on small farms (mean=1.4 ha, sd=1.4 ha, n=97).

Methods

Pilot Study

Before beginning to measure actual damage at Kibale, I first carried out a pilot study to explore the basic dimensions of the crop raiding problem. During interviews with 81 farmers, 13 different animal species were identified as causing damage (Naughton-Treves, unpubl. data). The animals described as worst pests varied according to village (n=7) and distance from the forest. Baboons and bushpigs were most frequently identified overall; at 3 km from the forest, birds and rodents replaced all other animals as "worst pests", while farmers on the forest edge complained additionally about elephants, chimpanzees, and redtail monkeys. Despite ubiquitous complaint, visible signs of damage were only encountered within 300 m of the forest edge . Farmers respond to crop loss by guarding (60%), leaving land fallow at the forest edge (50%), placing traps,

snares, or poison bait in their fields (15%), or abandoning cultivation of their farm altogether (4%).

Based on the pilot study, the following research objectives were defined:

(1) Quantify patterns of crop loss to wildlife by the frequency, amount, and predictability of damage by different species, as well as their crop preferences;

(2) Using two levels of analysis (the field and the village), test contextual variables, such as human population density, guarding, hunting and distance from the forest, as predictors of damage.

Monitoring Damage

Six villages were selected to monitor crop damage in relation to distance to the forest and other landscape features (Figure 3-1). Villages were selected to fulfill three criteria: (1) crops had to be present within 0.5 km of the forest boundary; (2) the village had to be accessible by bicycle from Makerere University Biological field station; and most importantly, (3) the citizens had to approve of the research to be done on their farms. A straight line distance of ~25 km separated the northernmost and southernmost villages of this study (Sebitoli and Nkingo respectively).

At each of the six villages, a grid was superimposed on farms. This grid ran approximately 1.0 km along the forest boundary, and extended 0.5 km away from the forest edge. Within each grid, crops, guarding huts, domestic compounds, fallows, and property boundaries were mapped at a resolution of 250 m^2. Intercropping regularly occurred, so a grid cell of 250 m^2 could contain as many as 5 crops. Fallows were mapped and categorized by age (<1 year, 1-6 years, >6 years old) based on property owners' reports and the presence and stature of woody vegetation . These maps were updated each planting season

(twice a year) to account for crop changes, fallow aging, forest remnant clearing and construction activity.

For 2 years, each village was visited on a weekly basis and the grid was completely canvassed for crop damage by teams composed of pairs of five assistants and myself. Animals were only occasionally viewed foraging in farms, therefore it was necessary to rely on spoor, dental impressions in plants, diggings, wadges, and other physical remains to identify the animal causing the damage. Crop damage by livestock began to be recorded 6 months into the study (means for livestock damage are adjusted for the truncated monitoring period).

Each season, accuracy, and reliability of species identifications were tested on events of known origin in blind interobserver tests. Observers were unanimous with regard to the animal responsible for the damage, except for damage caused by the closely related *Cercopithecus lhoesti* and *C. ascanius*. For these two species, identifications were at times confused (>80% concordance) so in all analyses I combine these congeners and refer to them as redtail monkey (*C. ascanius*), which was assumed to be responsible for the vast majority of such events (90% in actual observed raids, n=19) and are also thought to be the numerically abundant species. Concordance of interobserver tests in distinguishing the damage done by a third cercopithecine, the vervet monkey, or that done by baboons was higher than 95%. It was not possible to test concordance for crested porcupine or civet (*Civettictis civetta*) damage due to infrequent occurrences. In addition, amounts of damage and distance measures were calibrated by having observers sequentially canvass the same area.

Damage by rodents (other than the crested porcupine) was not measured because a) the focus of this study was on large (>3 kg) vertebrates, b) farmers

complained of rodent damage primarily on harvested and stored food versus standing crops, and c) fine scale damage was difficult to measure accurately over large areas. Note that rodent damage is not assumed to be insignificant (S. Lahm, unpubl. data; Kamarudin & Lee 1989), rather it is posed as a subject for future research.

The amount of damage was recorded by counting damaged stems of individually planted crops (e.g., bananas, maize, cassava, yams) and converting this to m^2 using average planting densities for each crop. Damage on sown crops (e.g., sorghum, millet, beans) was measured directly in m^2 (cf. Sukumar 1989). Crop maturity and parts consumed were noted. Also the distance to the forest boundary (from closest point of damage) and the distance to the nearest old fallow (>6 years) or natural vegetation feature of greater than $900m^2$ was recorded. Thus, the exact context of each damage event was recorded in relation to the mapped grids. Because monitoring data were collected on a weekly basis, the age of damage events in days since the last time the grid was canvassed was also recorded. Damage which was less than 48 hours old was unambiguously distinct from older damage. Among older events (over 48h), interobserver tests suggested that precision remained within approximately 48h intervals. Thus three categories of age of events was established (0-1, 2-3 and 4-6 days elapsed).

Crop preference by animal type was estimated using frequency of strikes on a specific crop as a percentage of total frequency on all crops consumed by the animal in question. Significance was assessed using a chi-square analysis based on the area available under different crops, corrected for the proportion of time that crops were edible for wildlife during one season.

Determining Independence

In order to draw stronger inferences about field vulnerability one needs to delineate statistically independent forays. Forays by wildlife into farmlands often damaged multiple crops in separate fields. If damage to every grid cell (250 m^2) were recorded as a separate event, the sample of events would be inflated by the non-independence of adjacent cells damaged by the same animal or group of animals. On the other hand, frequent raiders may make multiple forays and retreats, leaving a scatter of damage due to separate events (pers. obs.). Because I am interested in the foraying behavior of animal species and the relative vulnerability of crop assemblages, statistically independent events should encompass the sum of cells damaged between the exit from and return to natural vegetation. The challenge is to identify forays and returns based on indirect evidence.

What remains is to distinguish a single foray in which animal(s) damaged several cells, from multiple forays leading to many separately damaged cells. I approached this problem by assuming that an animal or group of animals damaging multiple cells began feeding on crops in one cell and moved directly to the next cell. Thus, the distance of the second cell of damage from the forest (assumed source of the animals) was much less relevant than the distance between one cell and the next cell. With this assumption in mind, it seems realistic that the probability of two strikes being related is a decreasing function of distance between the strikes. To use this model of crop-raiding to assess independence of events requires two more steps: 1) a means of calculating the density function or probability of damage at ever increasing distances from a starting cell, and 2) a means of calculating the background level of independent events by each animal throughout the monitored area.

Step 1 requires calculation of the ratio of damaged cells to undamaged cells in a ring surrounding a starting point. From the complete dataset of cells (250 m^2) damaged, thirty cells were chosen randomly for each of the five focal animals with a large sample size (elephants, bushpigs, baboons, chimpanzees, redtail monkeys). The thirty cells represented the starting point or 'epicenters' for the subsequent calculation. Cells surrounding the epicenter at fixed distances were then examined for damage. For each epicenter, this method yielded a column of numbers representing distance from the epicenter (x-axis) and number of damaged cells per area covered (y-axis). This exercise was repeated thirty times for each type of animal and the results averaged within each type.

At some distance from the epicenter, the density of damaged cells is expected to reflect random events (i.e., the damage was caused by the same animal on different forays or by different animals altogether). However, the random or background level of simultaneous yet independent events is expected to vary by type of animal. Therefore, for each species, I estimate the background probability at which independent events might be expected to co-occur in the same 48 hour period (Step 2).

Without direct observation of individuals, I was constrained to an indirect method of calculating a background probability. The percentage of weeks in which a set unit area was damaged by one type of animal over the course of two years is the best estimate available for the frequency with which independent events occur. I calculate this frequency only for areas which suffered damage from the species in question to make this a conservative estimate. The results indicated dramatic differences by animal type in the probability that independent events would co-occur: elephants= 4±4%, baboons= 5±5%, chimpanzees= 7±4%, bushpigs= 10±11%, and cercopithecines= 26±14%. Note

that this method controls for area under standing crops. These values may, in part, reflect population densities, foraging strategies and range sizes of the animals on the edge of Kibale National Park (KNP). The high standard deviations reflect the variability with which different areas are visited by these animals.

The final stage in the analysis of independence is the determination of the distance at which cells suffered, on average, the same frequency of damage as predicted by the baseline probability values. Any damage occurring within this distance is considered to be due to one foray (vicinity of dependence). For example, 25 meters is the mean distance separating a randomly chosen epicenter from all cells with a 26% probability of damage by redtails; therefore redtail damage events are designated as independent if they lie further than 25 m from each other in the same 48-hour period (the vicinity of dependence).

Analysis of variation in damage at the level of the village and the field

Contextual variables used to predict damage were identified from pilot research at Kibale and elsewhere, and from local farmers' reported defensive strategies. The variables were tested at both the level of the village and the field. Using two levels of analysis offers insight into the effect of individual, collective and park-level management on patterns of wildlife foraging on crops.

For each village, I first calculated the amount of two preferred crops devalued by their distance from the forest, using the following index (I):

$$I_{animal,village} = \frac{\sum(S_1 \ldots S_n)}{\sum(D_1 \ldots D_n)/n}$$

where S is the area (m^2) of n fields of the given animal's two most preferred

crops, and D is the shortest perpendicular distance (m) between each of n preferred crop fields and the forest edge. This index weighs preferred crops more heavily if they lie close to the forest.

Each village received a relative ranking of attractiveness, A, based on the ratio of its index, I, to the sum of I for all sites. For example, for the village Sebitoli and its attractiveness to bushpigs, in one case, A is calculated as

$$A_{Sebitoli} = \sum_{n=5\ animals} \left(\frac{I_{bushpig,\ Sebitoli}}{\sum I_{bushpig,\ all\ villages}} \right)$$

The attractiveness of a given village for a given animal ($A_{bushpig,\ Sebitoli}$) could range from 0 to 1, depending on how much preferred crop that village had compared to other villages. The value of $A_{Sebitoli}$ (the sum of $A_{animal,\ Sebitoli}$ for 5 animals) could theoretically vary from 0 (if the village had no preferred crops of any of 5 species) to 5 (if one village had all the preferred crops for all 5 species), but in practice, village attractiveness summed for 5 species varied from 0.3 (Kanyasohera) to 1.2 (Nyabubale). Ultimately, the index of attractiveness (A) reflects the relative amount of preferred crop for 5 wildlife species present at each of 6 villages.

The above calculations provide me with the expected values for frequency of crop foraging events. The observed frequency was derived from the number of events by a given animal at one village divided by the number of events by that animal at all villages. Thus, observed and expected are in the same dimensionless units and can be compared directly for deviations from the expected.

In an effort to explain the deviations from the expected (observed minus A), I tested four contextual variables related to villages: 1) % fallow, 2) guarding intensity, 3) hunting intensity, and 4) human population density. Nonparametric Kruskal-Wallis tests are reported to compare mean ranks between villages.

Fields were chosen for the second analysis because they represent discrete units of relevance to both animals and farmers. Six variables were measured to characterize fields: 1) field size (m^2), 2) distance from forest (m), 3) distance from other natural vegetation (m) which included fallows older than 6 years, 4) guarding intensity (see below), 5) hunting intensity (see below), and 6) sight distance (see below). Using mapping software (Turbo Map II™), a single field was defined as an accumulation of all pixels (25 m^2 map cells) of a certain crop lying within 20m of each other. This objective definition allowed me to determine field size even with complex geometry due to intercropping. For example, maize fields thus defined ranged in size from 2 to 347 pixels (50 m^2 to 8675 m^2).

A multiple regression was performed separately for each of three locally abundant crops, brewing bananas (*Musa spp.*: n= 68 fields), maize (*Zea mays* : n=180 fields) and cassava (*Manihot esculenta* : n=87 fields). Due to the fact that each animal showed different crop preferences, regressions were run separately for each of the top five raiding wildlife species. If a given village never suffered damage from a given animal (e.g., elephant damage was never reported at Nkingo: Figure 3-1), its fields were not included in tests for that animal.

An index of guarding intensity was calculated for each farm, based on the following factors:

(1) the number of weekly observations in which individuals were guarding over the course of 100 weeks was converted to a rank order

ranging from 0.0 to 3.9, where 0.0 corresponds to fewer than 3 observations of guarding and 3.9 corresponds to over 96 observations. (2) a record of fences, guarding huts, employed guards, scarecrows etc., over the course of the study, was tallied as presence/absence of nine such defenses (1= present, 0=absent). These values ranged from 0 (no defenses observed) to 4 (guard dog, two guarding huts and employed guards) depending on a sum of each farm's investment in defense.

Factors 1 and 2 above were added to compute the index of guarding which resulted in values ranging from 0.0 to 7.2. This rough index presumably fails to distinguish between farms with minor variation in guarding schedules or investments but certainly distinguishes farms lying near the extremes. This measure sought to encode variation in defenses but separating the relative effectiveness of each type of defense was beyond the scope of this study.

An index of garden hunting intensity was calculated based on a tally over two years of traps, snares, poison bait, dogs, and remains of butchered animals found on farms (1 point for each observation of a new sign of hunting, e.g., the same trap observed over several weeks received only one point). Summing this tally yielded values ranging from 0 to 5 (mean=0.35±0.95, n = 99). Forest hunting levels were not estimated because individuals typically enter 2 to 8 km into the forest to hunt (Okwilo, park guard, pers. comm), making it inappropriate to estimate and differentiate the consequences at a field or village level.

To estimate the distance at which a guard could hypothetically spot a raiding animal entering a field, an index of sight distance was calculated based on a variation of a method discussed in Schemnitz (1980). For each of the 13 major field types planted (e.g., maize and cassava, maize alone, brewing bananas, etc.) as well as for new, recent and old fallows (<1 year, <6 years, and

>6 years), 3 fields were randomly selected. In each field, an object 1m high was hidden by one observer unseen by 3 other observers. From a distance of at least 40m, the three other observers began to search for the object, and upon spotting it, recorded distance to it. The distances were averaged between observers and within the field types. The object roughly corresponded to the height of a bushpig, the largest crop-raider, not including elephants. Sight distance was not estimated for elephants which raid nocturnally at Kibale without exception. Sight distance was later entered into mapping software and averaged within disks of three different sizes (radius=5m, 15m, and 90m).

Human population density was estimated by the number of compounds per ha of farmland for each site. Based on 219 household surveys around Kibale, the average number of individuals per compound was approximately five.

Collinearity between predictor variables might distort results of multiple regressions, so the initial step in predicting damage was to sort out predictor variables which were highly correlated. The criterion for this was set at $r \geq 0.7$.

Initially, a stepwise regression was employed incorporating all 5 predictor variables (field size, distance from the forest, index of guarding, index of garden hunting and sight distance). This method allowed me to determine which variables were influential without reducing degrees of freedom, but did not allow me to determine semi-partial correlation coefficients (one variable's influence independent of other variables). Following this, I calculated a multiple regression using only those variables identified in the stepwise analysis to determine the independent influence of each variable.

Results

Comparison of Damage Between Animals

Determining the vicinity of dependence (the maximum distance separating damaged cells due to the same foray) for each animal was the first step for all subsequent analyses. For the top five animals, the vicinity of dependence was: cercopithecines= 25 m, bushpigs= 175 m, chimpanzees= 290 m, baboons= 520 m, and elephants= 710 m. Imposing this independence criterion on the data reduced the sample from 2635 events to 1873 independent events. The reduction was most pronounced for elephants; 71 recorded events dropped to 34 independent events. Seventeen different species of vertebrates were recorded damaging crops over a two year period at the six sites (Table 3-1).

Total frequency and amount of damage by the top five wildlife species and livestock is shown in Figure 3-2. Cercopithecines were the most frequent forager on crops around Kibale's edge, causing 51.8% of all independent damage events. Second most frequent were livestock with 17.7% events (goat --*Capra sp.*, and cow --*Bos sp.*, combined), and third were baboons at 9.6%. Comparing the area of crops damaged (Figure 3-2) by each animal reveals a different order, baboons (24% of total damage), followed by elephants (21%) and livestock (16%).

The average amount of damage caused by an animal in a single event is shown in Table 3-2. Elephants cause greater damage in a single event than does any other animal (mean=874±1530 m^2, maximum=6510 m^2).

To determine the predictability of damage caused by each event, I calculated a regression based upon the frequency of events suffered by a field and the percentage of that field destroyed over the course of the study. The percentage of variance explained (r^2) is thus a relative indicator of the

Table 3-1: List of animals responsible for observed damage at 6 villages around Kibale National Park (KNP).

Common Name	Scientific Name	Villages observed N=6	% of farms damaged N=97
redtail monkey*	Cercopithecus ascanius	6	85
domestic goat	Capra sp.	6	75
palm civet	Nandinia binotata	6	25
bushpig	Potamochoerus porcus	5	70
olive baboon	Papio cynocephalus	5	70
chimpanzee	Pan troglodytes	5	15
black and white colobus	Colobus guereza	4	8
domestic cow	Bos sp.	3	12
elephant	Loxodonta africana	3	8
African civet	Civettictis civetta	3	4
red duiker	Cephalophus spp.	2	2
crested porcupine	Hystrix africae-australis	1	3
vervet monkey	Cercopithecus aethiops	1	2
bushbuck	Tragelaphus scriptus	1	1
cane rat	Thryonomys swinderianus	na	na
guinea fowl	Guttera edouardi	na	na
speckled mouse bird	Colius striatus	na	na

*includes damage by Lhoesti's monkeys (Cercopithecus lhoesti).
** na (not available): animals for which systematic data were not collected.

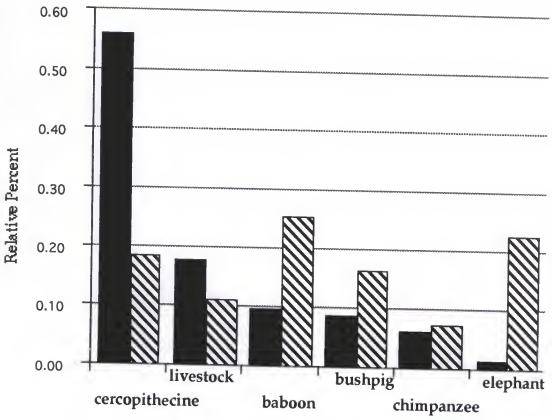


Figure 3-2. Relative contributions of the major crop raiding animals to the overall frequency of events (■) and overall damage (▨): June 1992 through May 1994.

Table 3-2: Frequency and amount of damage to crops by animals around KNP

Common Name	Scientific Name	# events	Amount damaged (sq. m.) per event mean ± s.d. (range)	Amount damaged (sq. m.) total	Amount damaged (sq. m.) % of total area°°
redtail monkey*	Cercopithecus ascanius	1252	16 ± 23 (1-625)	19519	15%
domestic goat	Capra sp.	306	25 ± 38 (1-329)	20486°	16°
olive baboon	Papio cynocephalus anubis	228	136 ± 350 (1-2774)	31016	24%
bushpig	Potamochoerus porcus	208	94 ± 180 (1-2080)	19812	15%
chimpanzee	Pan troglodytes	146	61 ± 219 (3-2500)	8815	7%
domestic cow	Bos sp.	108	129 ± 382 (3-2000)	°	°
vervet monkey	Cercopithecus aethiops	103	28 ± 62 (1-625)	2282	2%
palm civet	Nandinia binotata	38	29 ± 16 (1-102)	826	1%
elephant	Loxodonta africana	34	874 ± 1530 (9-6510)	28098	21%
African civet	Civettictis civetta	12	na	na	<1%
bw colobus	Colobus guereza	11	11 ± 7 (1-21)	na	<1%
crested porcupine	Hystrix africae-australis	6	7 ± 7 (1-19)	na	<1%
red duiker	Cephalophus spp.	6	na	na	<1%
bushbuck	Tragelaphus scriptus	3	na	na	<1%
speckled mouse bird	Colius striatus	na**	na	na	na
guinea fowl	Guttera edouardi	na	na	na	na
cane rat	Thryonomys swinderianus	na	na	na	na

*includes damage by L'hoesti (Cercopithecus lhoesti) monkeys.
** na (not available): animals for which systematic data were not collected.
° data for goats and cows are lumped and reported in the row for goats.
°° area under crops (total of 6 villages over 23 months=13 ha)

Over 90% of all independent events occurred within 160 m of the forest boundary (Figure 3-3). The distance at which 90% of events occurred varied by animal (smallest for elephants (126 m) and chimpanzees (129 m), greatest for bushpigs (245 m) and palm civets (290 m) as shown in Figures 3-4.

Thirty different crops were damaged by wildlife or livestock. Each animal showed a different preference (Table 3-3). Chimpanzees and redtail monkeys damaged banana crops with greater frequency than predicted by crop availability. Baboons and bushpigs targeted maize and cassava preferentially. Elephants appeared to damage banana fields more than expected by chance, but low sample size precludes a firmer conclusion.

Comparison of Damage and Analysis of Predictor Variables at the Village Level

Crop loss varied considerably between villages in the amount of damage suffered, and assemblage of animals causing damage (Figure 3-5). Baboons, bushpigs, redtail, and lhoesti monkeys damaged crops at five villages, elephants at three, porcupines at two, and vervet monkeys at only one village (Table 3-1). Examining the five wildlife species responsible for the most damage, I found that intervillage variation in frequency was significant for chimpanzees (Kruskal-Wallis $H=16.5$, $p=0.0056$), bushpigs ($H=18.6$, $p=0.0023$) and elephants ($H=22.9$, $p=0.0004$). Pooling damage for all animals, Nyabubale suffered 5.4 times more damage per unit area of crops planted than did Nkingo.

Mindful of the marked preference of each wildlife species for certain crops and the strong relationship between distance from the forest and damage (Figures 3-3, 3-4), I sought to explain intervillage variation. Using the index of attractiveness (A: see methods) for each village to predict damage, deviations from the expected were apparent (Figure 3-6).

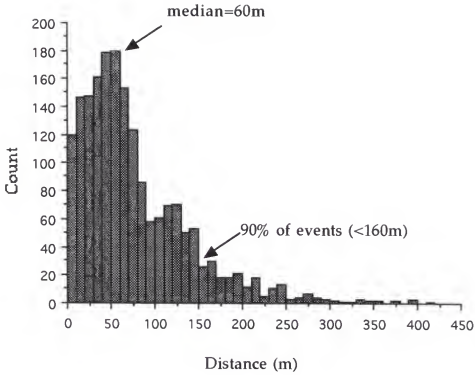


Figure 3-3. Frequency distribution of crop raiding events by all wildlife as a function of distance from KNP forest edge (N=1873 independent events). The arrows indicate the distance under which 50% (median) and 90% of data points lie.

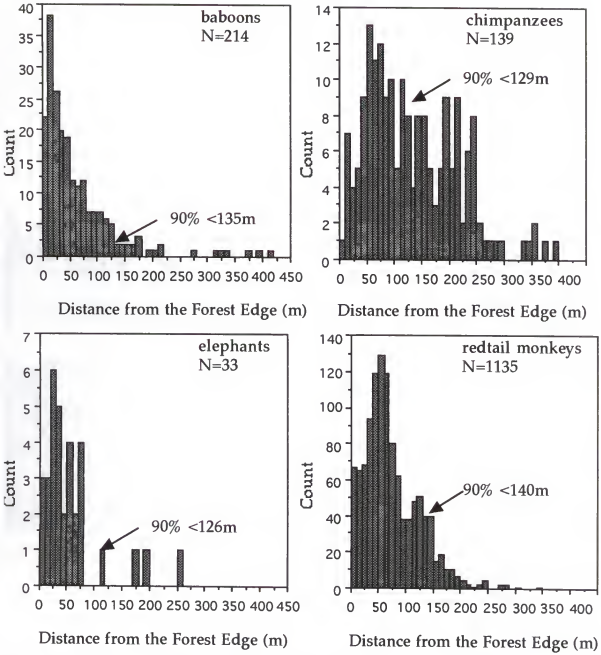
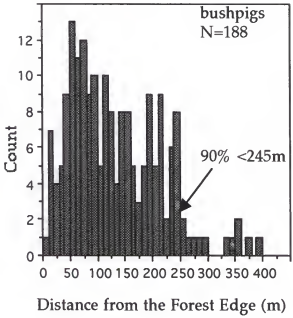


Figure 3-4. Frequency distributions of distances from the forest edge for independent crop raiding events by 4 species at Kibale National Park, June 1992 through May 1994. The arrow indicates the distance below which 90% of events were recorded. Sample sizes represent independent events.



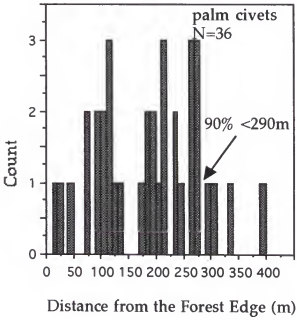


Figure 3-4-- continued.

Table 3-3: Crop preferences of the five wildlife species responsible for the most damage around KNP.

Animal Type	Scientific Name	Crop Preference** First	Second	Third	Test Result
baboons	*Papio cynocephalus*	maize	sweet potato	ground nuts	$\chi^2=31$ *
bushpigs	*Potamochoerus porcus*	cassava	yam	sweet potato	$\chi^2=165$ *
chimpanzees	*Pan troglodytes*	brewing banana	sweet banana	sugar cane	$\chi^2=30$ *
elephants	*Loxodonta africana*	sweet banana	cooking banana	sweet potato	$\chi^2=4$
redtail monkeys	*Cercopithecus ascanius*	sweet banana	maize	brewing banana	$\chi^2=295$ *

* chi-squared test for first crop: $p<0.05$
** calculated as frequency corrected for availability (area and time)

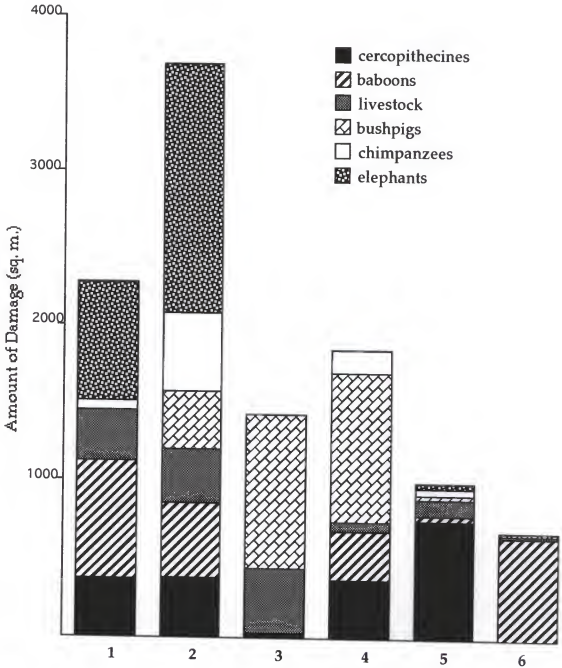


Figure 3-5. Crop damage at villages around KNP (1=Sebitoli, 2=Nyabubale, 3=Kanyasohera, 4=Kabucikire, 5=Rurama, 6= Nkingo) caused by 5 wildlife species and livestock.

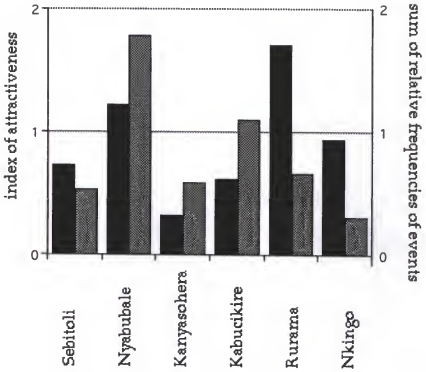


Figure 3-6: Comparison of expected (■) frequencies to observed(▩) frequencies of crop foraging events by 5 wildlife species at each of 6 villages around KNP. See methods for determination of y-axis values.

In a test of correlation between four predictor variables and the deviation from expected damage, only the index of garden hunting intensity was significant ($H=10.6$, $p=0.034$). This relationship was stronger when elephants were excluded ($H=11.5$, $p<0.03$).

Comparison of Damage and Analysis of Predictor Variables at the Field Level

The distribution of damage between fields was positively skewed: on average, banana fields suffered 3.5% damage by area (n=56 fields, sd=7.2, range=0-44); cassava fields 6.8% (n=62 fields, sd=19.5, range=0-100); and maize fields 5.5% (n=151 fields, sd=14.5, range=0-100). If one excludes fields that were never damaged, larger differences between the crops appear (Figure 3-7).

The multivariate analysis of damage to fields required an assessment of collinearity of predictor variables. Of the 6 predictor variables listed in the Methods, only 5 were used. Distance to forest and distance to natural vegetation were highly correlated ($r>0.7$); so distance to forest was used. Sight distance was calculated in three ways (see Methods) and the three measures were also highly inter-correlated. I opted to use sight distance in a radius of 15 m in preference to 5m or 90m, because this measure incorporated information about sight distance over 5m but did not obscure variation in vegetation structure, a weakness of the broader measure.

The results of the multiple regression are summarized in Table 3-4. Both frequency and amount of crop loss were regressed on the predictor variables for each type of animal. In three cases, frequency and amount did not show concordance in association with a predictor variable (elephant amount, baboon amount and chimpanzee frequency).

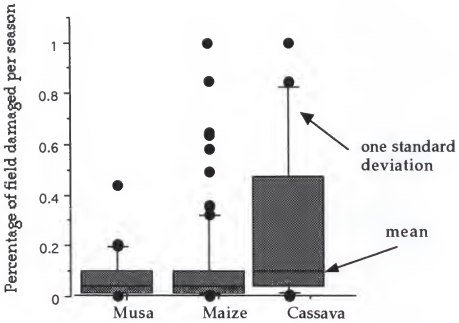


Figure 3-7: Extent of damage to three crops in an average season. The box plots depict the mean (the horizontal line dividing the grey rectangle), the range within which 50% of points lie (the grey rectangle), the standard deviation (as indicated) and outlying points (●). Sample size for Musa (n=68 fields), Maize (n=180), Cassava (n=88).

Table 3-4 Predicting Damage to Fields

Animal Type	Crop Loss	Maize Predictors † distance	guarding	sight distance	Brewing Bananas Predictors † field size	distance	guarding	Cassava Predictors † sight distance
baboons	frequency °	-**						+*
	amount °°	-**		+*				+*
bushpigs	frequency	-*						
	amount	-*						
chimpanzees	frequency					-*		
	amount							
elephants	frequency						+**	
	amount				+***		+*	
cercopithecines	frequency		+***	-*				
	amount		+**	-*				

†: predictor variables identified in stepwise regression but significance levels derive from multiple regression.
°: frequency was quantified as # of events per week suffered by a given field.
°°: amount reflects the % of a field's area damaged per week.
+/- reflects the direction of the correlation between the predictor and the response variable (crop loss).
blank cells are non-significant correlations.
* $0.05 \geq p > 0.01$ ** $0.01 \geq p > 0.001$ *** $p \leq 0.001$

Table 3-4 presents significance and direction of individual predictors but the F-values for the multiple regressions follow:

(1) Maize Fields: the frequency of baboon events on maize was negatively correlated with distance from the forest (n=145, F=10.1, p=0.0018); the amount of damage done by baboons was negatively correlated with distance from the forest edge and positively correlated with sight distance (n=144, F=7.2, p=0.0011). Frequency and amount of redtail events were both negatively correlated with sight distance and both positively correlated with the index of guarding (frequency: n=151, F=9.1, p=0.0002; amount: F=5.6, p=0.0044).

(2) Brewing Banana fields: the frequency and amount of damage by elephants were both positively correlated with the index of guarding (frequency: n=35, F=10.5, p=0.0027) while amount was also positively correlated with field size (n=35, F=6.1, p=0.0006). The frequency of chimpanzee events was negatively correlated with distance from the forest (N=42, F=4.2, p=0.046).

(3) Cassava fields: the frequency and amount of damage by baboons was positively correlated with sight distance (frequency: n=65 fields, F=4.2, p=0.046; amount: F=4.1, p=0.047). Although no single predictor variable explained a significant proportion of variance in frequency of bushpig events on cassava fields, a multiple regression model incorporating all five variables was significant (n=44, F=2.6, p=0.038).

There were significant inter-correlations of certain predictor variables. For example, farmers guard fields close to the forest more intensely, and fields with greater sight distance (e.g.,maize, groundnuts).

Discussion

Principal Wildlife Species Foraging on Crops and their Patterns of Damage

The diverse assemblage of animals present at Kibale is reflected in the diversity of animals damaging crops. Primates (chimpanzees and baboons, plus redtail, L'hoesti, and vervet monkeys) accounted for 71% of recorded events and 48% of total damage to crops. Primates also dominate the assemblage of crop raiders at nearby forest sites of Budongo, Bwindi, and Ituri (Hill, 1993; CARE, 1994; Mubaleme, J. pers. comm.). At all these sites, baboons and certain cercopithecine monkeys rank as worst pests, indeed among primates these appear to be best able to exploit the forest/agriculture edge (Masau and Strum 1984; Else 1991; Thomas 1991).

Around other African parks and reserves, a great diversity of animals have been recorded damaging crops (Table 3-5). Dominating the lists of wildlife pests are some of the same animals identified in this study, namely baboons, cercopithecine monkeys, bushpigs, and elephants. Such medium- to large-size mammals (> 3 kg) receive higher ranking than do rodents and birds (Table 3-5). This accords with the general observation that larger animals receive greater attention, both in management response and in farmers' complaints (Bell 1984*a*). However, other researchers have proposed that small animals, rodents in particular, cause greater damage (Dudley et al. 1992; Lahm 1994). In the absence of systematically collected field data, the relationship between damage by small versus large animals remains unclear (Caldecott 1988).

Table 3-5: Problem wildlife species around African parks and reserves.

		Problem Animal Ranking (reference follows study site)						
		Uganda			Tanzania			
Order		Kibale (1)	Bwindi (2)	Budongo (3)	Kilimanjaro (4)	Manyara (5)	Mikumi (6)	Selous (7)
Artiodactyla	bushpig	2	6	2	2		1	4
	warthog					4		6
	hippopotamus					5	4	2
	kudu							
	sitatunga							
	buffalo					3	5	3
	duiker			9				
	eland							
	bushbuck			5				
Primates	monkeys°		1		1	6	2	5
	baboon	1	2	1	5	2	1	6
	chimpanzee	5	7					
	mandrill							
	gorilla							
	white-collared managabey							
	vervet	8		3				
	redtail	3						
Proboscidea	elephant	4	5			1	3	1
Rodentia	rodents°	6	4	8	3		7	7
	porcupine		8	7				
	striped ground squirrel			6				
Lagomorpha	springhare							
Carnivora	palm civet	7						
	jackal							
Aves	birds°	6	3	4	4	7	8	8

° unspecified or uncertain

References : 1. this study
2. CARE 1995: n=316, 10 enumeration areas from Park boundary.
3. Hill 1994: n=245, villages adjacent to forest, forest fragments, and forest plantations.
4-7. Newmark et al. 1994: n= 1396, within 12km of reserve boundary.

Table 3-5 continued

Problem Animal Ranking (reference follows study site)

Order		Gabon Country-wide (8)	Zambia U. Lupande (9)	Zimbabwe Bulilimamangwe (10)	Malawi Kasungu (11)
Artiodactyla	bushpig	5	1	5	2
	warthog		6	5	
	hippopotamus		3		
	kudu		7		6
	sitatunga	6			
	buffalo	8		6	
	duiker				
	eland				5
	bushbuck				
Primates	monkeys°		2		
	baboon				3
	chimpanzee	10	4		
	mandrill	4			
	gorilla	7			
	white-collared managabey	8			
	vervet				4
	redtail				
Proboscidea	elephant	2	5	3	1
Rodentia	rodents°	1			
	porcupine	3			
	striped ground squirrel				
Lagomorpha	springhare			2	
Carnivora	palm civet				
	jackal			4	
Aves	birds°			1	

° unspecified or uncertain

References:
8. Lahm 1995: n=2926 respondents, random selection from entire nation of Gabon.
9. Balakrishnan & Ndhlovu: n=135, within Upper Lupande Game Management Area.
10. Hawkes 1991: n=966, up to 4th village from unsettled wildlife area.
11. Bell 1984a: n=80 adjacent to or within one farm of Park boundary (damage measured, not interviews).

Confounding our understanding of crop loss to wildlife is the often vague description of study area. Surveys of crop raiding carried out on a national basis (e.g., Lahm 1994) or in villages several km from natural vegetation (e.g., Hawkes 1991) are more likely to record birds and rodents as most problematic animals when compared to a similar study targeting farms immediately adjacent to or within a park or reserve (e.g., this study or Balakrishnan and Ndhlovu 1992). Productive discussion regarding the relative agricultural damage by different animals requires not only systematic data, but a careful delineation of the extent of the study area and its proximity to natural habitat.

The present study focused on farms lying within 0.5 km of the forest. Although this is a narrow band of farms, crop damage was recorded for animals of diverse sizes, from redtail monkeys (♀ = 2.9 kg, ♂ = 4.2 kg.: Harvey et al. 1987), to elephants (♀ = 3000 kg, ♂ = 5000 kg.: Estes 1991). This allows for detailed comparisons of patterns of crop foraging by animals of varied sizes, population densities and behaviors.

Interpreting the pattern of damage by animals of disparate size requires careful attention to scale factors, both spatial and temporal. Therefore it is appropriate to make such comparisons at different levels (e.g., the field, the farm, the village, and the park) and over different time periods.

Every week, redtail monkeys cause damage to many farms around Kibale National Park. While each event is predictably small, the sum of their damage over two years at the level of the park, matches or exceeds that for two larger animals (chimpanzees and bushpigs). The pattern of elephant damage is quite

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Every week, redtail monkeys cause damage to many farms around Kibale National Park. While each event is predictably small, the sum of their damage over two years at the level of the park, matches or exceeds that for two larger animals (chimpanzees and bushpigs). The pattern of elephant damage is quite different. Most farms around Kibale suffer no damage by elephants. However, when elephants visit a single farm, the amount of damage is unpredictable and

may be overwhelming, destroying an entire farm's production. Summing elephant damage at the park level over two years, the amount of damage they caused was exceeded only by baboons. Moreover, elephant events are highly localized (Hawkes 1991; Dudley et al. 1992). Thus at the park level, redtail monkey damage appears to be relatively evenly spread among farms on the edge of the forest, while elephant damage appears clumped.

Considering that most decisions regarding planting and defending crops around Kibale occur at the level of the field or the farm, this study emphasizes this level of analysis. However, it is worth noting that smaller animals may also exhibit clumped damage patterns (e.g., rats in cocoa plantations: Kamarudin and Lee 1989), however the clumps are typically observed at the level of individual plants, a fine scale resolution beyond the scope of this study.

Aside from variation in the distribution or magnitude of damage by the wildlife species, each animal exhibited a different crop preference. Bushpigs targeted tuber crops (e.g., cassava and yams), baboons took sweet potatoes and maize, redtails ate sweet bananas and maize, chimpanzees ate the pith and fruit of brewing and sweet bananas, and elephants destroyed the entire plant of sweet and cooking bananas. Maize was consumed by all of the most frequent crop foragers although not necessarily out of proportion to its availability. Compared to the other preferred crops, maize is unique in that it has a short growing season, and ripens uniformly (see Chapter 5 for detailed analysis). Because maize fields are relatively small, they represent a discrete, super-rich food patch when ripe. These characteristics make maize a risky crop for farmers to grow near the forest edge.

Identifying Predictor Variables at the Level of the Village and the Field

Predicting wildlife foraging behavior in a biologically and socially complex system is fraught with difficulties. Crop loss varied considerably between villages in the amount of damage suffered, and the assemblage of animals causing damage. This variation was unexpected, considering the proximity of the villages to one another (e.g., Kabucikire and Kanyasohera are <1 km apart). The 'index of attractiveness' (amount of preferred crops divided by average distance of preferred crops) did not fully explain intervillage variation.

Human population density varied between sites (mean=272±167 individuals per km^2), but did not explain the amount of damage, nor the animals raiding. Elsewhere, human population density has been linked to variation in patterns of wildlife crop damage. Specifically, farmers residing in densely populated areas are more likely to suffer damage from small versus large animals (Newmark et al. 1994). Relative to study sites in neighboring Tanzanian parks, all six villages in this study lie at the high end of human population density (Newmark et al. 1994). Yet farmers at Kibale suffer crop loss to medium to large animals, not only small animals (contra Newmark et al. 1994). Again, discrepancy in the size of the study area may account for contrasting observations between sites. If this study had monitored damage up to 12 km from the forest edge (as per (Newmark et al. 1994), it is likely that rodents and birds would figure more prominently as problem animals. Evidence to support this prediction derives from the data indicating that over 90% of crop damage was observed to occur within 200 m of the forest boundary (Figure 3-3).

Farmers were able to affect the amount of crop loss to wildlife (other than elephants), at the village level, by setting traps, snares and poison and by owning hunting dogs. Yet only 15% of farmers were observed to use these traditional

methods. No farmers at Kibale were observed attempting to kill elephants in contrast to agriculturalists elsewhere (Milton and Binney 1980; Sukumar 1994). Apparently legal prohibition discouraged farmers from hunting. Meanwhile, hunting did not influence the amount of crop loss in an individual field but a non-hunter might expect to benefit from the hunting activities of her neighbors. The discrepancy in the effectiveness of hunting between the field and the village level deserves attention in future research.

Many more farmers attempted to defend their crops by guarding than by hunting. Guarding is, of course, legal. However, multivariate tests did not show an association between guarding and the amount of crop loss at either the village or the field level. Given the scope of the study, actual efficacy of guarding by hour of investment could not be assessed. At the field level, the positive association of guarding and crop loss to redtail monkeys does not indicate that guarding attracts these animals; rather that farmers are responding to obvious risk, especially in relation to ripening maize. Moreover, farmers guard more frequently at the edge of the forest which may confound the results of a multivariate analysis in which both guarding and proximity to the forest are tested against crop damage. Animals were several times observed to await the departure of farmers to move into fields (Kavanagh 1980; Horrocks and Baulu 1988). Nevertheless, many farmers continue to invest their time and energy in guarding. Investment in guarding serves to measure an indirect cost of crop raiding: labor investment and lost opportunities (e.g.,children stay home from school to guard fields). From a methodological perspective, guarding is a complex behavior that is difficult to monitor accurately. Variation in guarding was more pronounced between individuals than between villages. Moreover, cooperative guarding between households was uncommon (8%, n=97 farms).

The fact that sight distance correlated positively with baboon damage may be best explained by the preference of baboons for low-growing crops (e.g., maize or sweet potatoes). Meanwhile, damage by the largely arboreal redtail monkeys showed a negative correlation with sight distance when feeding on maize. As sight distance encodes information about arboreal habitat, this result could indicate that arboreal travel routes potentially limit redtail movements.

At the field level, proximity to the forest was the strongest predictor of damage by baboons, bushpigs, redtail monkeys and chimpanzees. This represents a departure from farmers' reports of severe loss up to 3 km from the forest boundary. Analysis of this disparity and detail on farmer perceptions and coping strategies are presented elsewhere (Chapter 4). The skewed distribution of damage toward the forest edge does not mean that wildlife only raid at the forest edge -- in fact, elephant damage was recorded 2 km from Kibale's edge on a farm where elephants had last visited more than 50 years ago.

Ultimately, the explanation for the localized pattern of elephant damage remains a mystery, considering that they move throughout Kibale. The fact that elephants damaged only three villages becomes especially interesting given the history of elephant activity at these sites. Game department archives reveal persistent elephant damage at certain key sites (e.g., Sebitoli) dating to 1951. Elephant foraging patterns are likely to be shaped by a complex set of factors operating at a large scale (e.g., forest disturbance by logging in the north of Kibale, heavy poaching in the south).

The pattern of damage by different wildlife species has implications for farmers' capacity to absorb damage. An individual farmer suffering elephant damage is likely to view it as a catastrophic loss, which overwhelms damage caused by other animals. The size of the maximum elephant damage event

recorded in this study (0.7 ha damage in <2 hours) exceeds the size of 35% of farms at Kibale's edge (n=97). In this study, only elephant raiding caused entire farms to be abandoned (e.g., Sebitoli).

Conclusions

The combination of official vermin eradication programs and the conversion of Uganda's forest to agriculture during this century has reduced wildlife-human conflict with ferocious success at the national level. For example, in 1929, elephants ranged over 70% of Uganda, by 1959, they inhabited 17% of the country's area (Brooks and Buss 1962), and today they persist only within the 7.9% of national territory under protected area status (World Resources Institute 1994). Similarly, even forest edge specialists, such as baboons and redtail monkeys have been eliminated as forest remnants were destroyed (Baranga 1993). Few Ugandan farmers today need fear crop loss to medium to large wildlife species.

The results of this study indicate that, on average, <10% of crops are lost to wildlife in a narrow band of farms around Kibale. From a national or international perspective, this appears to be a trivial price for maintaining threatened habitat and biological diversity. Some would argue that the zone of heaviest crop loss (250 m beyond the forest boundary) provides ~3,000 ha of "extra" habitat for endangered wildlife species at Kibale (area calculated as per (Mugisha 1994). But living within this "extra" habitat are ~7,000 farmers who are frustrated and occasionally overwhelmed by crop loss to wildlife (population calculated by census and per (Mugisha 1994).

Nearly all the farmers living within 0.5 km of the forest on some occasion suffer crop loss to wildlife, most frequently to redtail monkeys, bushpigs and baboons. However, the 10% damage estimate from this study is not evenly distributed within the farming community. Bushpigs and baboons can destroy an entire maize or cassava field if it is not guarded. Elephants damage only a few farms at certain villages, but are undeterred by guarding and are capable of destroying one farm's entire production in a single night. Farmers living closest to the forest edge suffer greatest losses.

Many of these farmers attempt to reduce their risk of crop loss to wildlife by various methods, both legal (e.g., guarding) and illegal (hunting). Multivariate tests suggest that only hunting, and modification of field size or distance from the forest will have an effect of reducing risk. Indeed, no stratagem is identified here to reduce the risk posed by elephants.

Farmers owning relatively large farms (> 5 ha) have the greatest flexibility in coping with crop raiding. They can maximize the distance between their crops and the forest by planting less palatable crops near the boundary, or by renting out the most vulnerable parts of their farms. Most vulnerable are those individuals growing food crops on small farms (< 1 ha), adjacent to the forest, and at villages where elephant damage is common.

The discovery in this study that livestock damage to crops is comparable or exceeds that caused by many wildlife species is significant because rarely do people complain to the government or outsiders about livestock damage. The lack of complaint is explained by local perception that livestock are providing people benefits, and (perhaps more importantly) that victims of livestock belonging to another party have the right to demand compensation. Building local tolerance for wildlife damage to crops can draw on the example provided

by livestock. As one respondent put it, "Why should I feed these animals? These are not my animals."

Concerted effort should be made to channel benefits (e.g., from tourism revenue or employment opportunities) to the neighbors of Kibale, particularly to those who are absorbing the most crop loss. Considering that individuals do have some capacity to reduce their crop loss to wildlife other than elephants, direct compensation should be considered in the case of losses to elephants (Chapter 6). Maintaining elephants in a crowded landscape is therefore a profound challenge requiring intervention from institutions beyond the level of the village.

The government of Uganda is placed in the difficult position of protecting wildlife while guarding the property and lives of its citizenry. If the mandate to conserve wild animals and their habitat is considered a national interest, the local farmers must see short-term advantages to offset the immediate costs. Ultimately, the long term conservation status of Kibale National Park will be heavily influenced by the neighboring community.

CHAPTER 4

"WHY SHOULD WE STARVE SO THAT BABOONS MAY EAT?" PERCEPTIONS AND REALITIES OF CROP LOSS TO WILDLIFE AT KIBALE NATIONAL PARK, UGANDA

Introduction

The long term status of a protected area depends greatly on the support of local residents (Wells and Brandon 1992). Conservationists striving to build local support for protected areas often evaluate their success by surveying local attitudes. Hostile attitudes are often encountered where agriculturalists neighboring protected areas lose crops to wildlife (Mwathe 1992). In response to the bitter complaints of farmers, at several sites park managers are investing millions of dollars in erecting barriers to prevent wildlife from entering farmland (Blair and Noor 1979a; Litoroh et al. 1992). Elsewhere, projects are underway to compensate local residents for their crop loss via revenue sharing, and job opportunities, or to raise their tolerance for crop loss to wildlife by other means (Damiba and Ables 1993).

Despite considerable investment in efforts to reduce crop loss to wildlife and/or raise public tolerance, uncertainty persists regarding the actual magnitude or extent of the problem. Recent studies have revealed that local claims of damage are frequently inaccurate or exaggerated (Mwathe, 1992; Wakely, 1981). This discrepancy between perceived and actual damage is often attributed to local farmers' hopes for substantial compensation (Bell

1984*a*). With regard to naming the animals inflicting the greatest costs, several studies suggest that megafauna, such as elephants or rhinoceros, receive disproportionate blame for damage, while smaller animals, such as rodents or primates cause greater damage over time (Bell 1984*a*; Hawkes 1991). Similarly, domesticated animals may cause considerable damage to crops or plantations, yet their damage does not elicit such strong public complaint (Graham et al. 1992).

Few studies carefully compare local perceptions of crop loss with systematically measured losses (Kasperson et al. 1988). Missing at a broader level, is an examination of how social, institutional, cultural and psychological factors amplify people's perception of risk of crop loss to wildlife (Kasperson et al. 1988).

Given the politically volatile nature of human–wildlife conflict (anonymous 1994; Voyles 1994), and the high cost of current management options, there is a need for better understanding of how local residents perceive the severity of loss to different animals, and how their perceptions compare to measured amounts of damage. To achieve such an understanding, it is necessary to explore factors which influence local perceptions regarding crop loss to wildlife and the protected area itself.

In this paper, I compare the complaints of 'worst animals' by farmers around Kibale National Park with 2 years of data from systematic monitoring of crop damage by wildlife and livestock in neighboring farms. Perceptions of "most vulnerable crop" are also compared with the same monitoring data. Beyond revealing concordance and discrepancies in complaints versus actual damage, I test how variables, such as ethnicity, sex, length of residence, employment, and affluence, influence the naming of worst animals and most

vulnerable crop. Elsewhere these socioeconomic variables have been used to explain general attitudes toward protected areas (Aboud 1986; Baldus 1988; Lewis 1988; Newmark and Leonard 1991; Balakrishnan and Ndhlovu 1992; Fiallo and Jacobson in press). I examine how these variables, as well as the incidence of crop loss to wildlife, shape local perceptions of the purpose and benefits of Kibale National Park. Finally, in sharing the results of discussions regarding life on the edge of Kibale, I demonstrate how state ownership of wildlife as property amplifies local perceptions of vulnerability to crop loss.

The dynamics of the relationship between early agriculturalists and wildlife in East Africa has been a subject of broad interpretation. Some analysts conjure a harmonious relationship, and set this in juxtaposition to the modern partition of the rural poor from the land and wildlife held within national parks (Adams and McShane 1992). Others describe a fiercely competitive relationship (Parker 1984); while still others portray reverential attitudes toward wildlife among traditional people (Ville 1995). In all likelihood, people's attitudes toward wildlife varied from site to site, depending on a complex interplay of cultural and physical factors, and history of interactions.

Traditional methods for coping with crop loss to wildlife included planting widely dispersed fields, guarding, intercropping, and rotational planting (Goldman 1986). Communal ownership of wildlife allowed farmers to hunt in their fields, thereby hypothetically compensating for the costs of crop loss (Marks 1976; Vansina 1990). Nonetheless, crop damage by wildlife, particularly by elephants, made some arable land uninhabitable for sedentary farmers (Osmaston 1959; Vansina 1990). Early this century, colonial game

departments throughout E. Africa initiated militaristic campaigns to eradicate problem animals, such as elephants, hippopotami, and leopards, so as to allow the agricultural frontier to expand (Brooks and Buss 1962; Graham 1973; Booth et al. 1992; Ville 1995).

Kibale National Park (Figure 4-1) is a 766 km^2 remnant of a forest system that as recently as the 19th century extended south to the Virungas, and west to Zaire (Osmaston 1959). This formerly vast forest has been largely converted to agriculture, due in part to the tripling of the region's human population in the past three decades (World Bank 1993).

Currently, 54% of land within 1.0 km of Kibale's boundary is used in small holder agriculture (Mugisha 1994). Agriculturalists in the area belong to two predominant tribes, the indigenous Batoro, and the immigrant Bakiga who began arriving in the area during the 1950s (Turyahikayo-Rugyema 1974). The Batoro chiefs allocated land to immigrants on the outskirts of their settlements, hoping that this would buffer Batoro farmers from crop damage by wildlife (Kabera in Aluma et al. 1989). Today, both groups plant a mixture of over 30 species of subsistence and cash crops; among these, bananas (*Musa spp.*), maize (*Zea mays*), beans (*Phaseolus vulgaris*), yams (*Dioscorea spp.*), and cassava (*Manihot esculenta*) cover the greatest area. The proportion of these crops planted varies between tribes; Batoro favor brewing bananas, sweet potatoes, and are likely to leave more of their farm in fallow. Bakiga farmers plant more groundnuts, sorghum, and maize and use more intensive cultivation strategies. In both tribes, women generally assume responsibility for production of food crops, while men tend cash crops, such as brewing bananas which they distill into gin for sale on the local market.

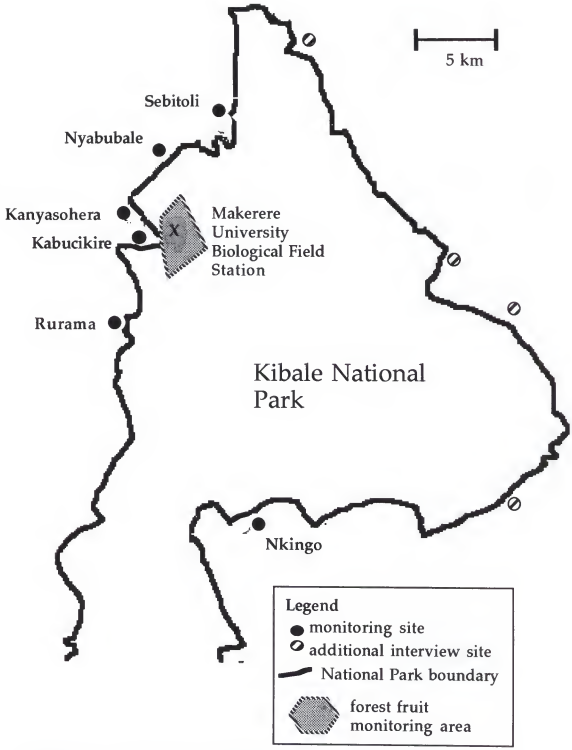

Figure 4-1. Locations of surveys and interviews of farmers around Kibale National Park, Uganda.

Farm sizes are small (mean =1.4 ha, sd=1.4, n=97) and population density is high (mean =272 individuals per km^2, sd=167 for land under small holder agriculture[1]). Within this diverse farming system, various animals forage on subsistence and cash crops, resulting in much frustration, and resentment of the park among local cultivators (Aluma et al. 1989; Forbes 1991).

Research Approach and Methods

Farmers around Kibale are frustrated by crop loss to wildlife and have long hoped for compensation from the government. My entrance into the community as a foreign investigator initially prompted hopes of compensation, particularly as Kibale is thought by many individuals to 'belong to foreigners'. Initiating research in such an environment carries two risks: a) that estimates of crop loss will be exaggerated; and b) that expectations left unanswered will lead to the alienation of a local community and a reluctance to participate in future research or park management activities.

Therefore, foremost in my research approach was to make data collection a transparent, participatory exercise. To this end, before any damage was measured, or any farmer interviewed, collective and individual permission was requested through the careful explanation of research goals. These goals were repeatedly reaffirmed throughout the study in formal and informal meetings. By and large, people were eager to participate in the

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[1] Farm size and population density figures were calculated only for land under small holder agriculture. Within 1.0 km of Kibale's boundary, land is occupied by small holder agriculture (54%), forest remnants (24%), tea estates (10%) and grassland (10%). Land uses other than small holder agriculture are assumed to have significantly lower human population densities.

study, in fact, some individuals residing in areas outside the study area subsequently complained about being excluded.

A second key step toward making the research participatory was to hire and train seven local farmers as field assistants. These seven individuals were fluent in local languages, familiar with social customs and agricultural practices, and had all suffered crop loss on their own farms. The contribution of these individuals in collecting data, leading discussions, and offering insight into the farming system cannot be overestimated.

Early in the study, participatory rural appraisal exercises were carried out at nine villages (IIED 1988; Chambers 1991). These exercises were coordinated with the elected village leaders (Resistance Council Chairman I or Secretary), and, on average, 40 people participated in each exercise. During these exercises, a rough time line was created by the participants documenting prominent events in the history of the village (e.g., arrival of different families, creation of the park, construction of schools, etc.). Maps were also sketched by participants which revealed landscape features of importance in their eyes (e.g., churches, forest patches, water holes, forest boundary, etc.). During the course of constructing the time line and maps, I posed a series of questions regarding crop loss to wildlife and possible defensive strategies. These questions launched animated and lengthy discussions which revealed, in part, people's perceptions of the problem.

Systematic data on the pattern of crop loss to wildlife and livestock was collected on a weekly basis for two years in 95 farms at 6 study sites (Figure 4-1, see Chapter 3 for details on monitoring methods). During the final months of the monitoring program (March and April 1994), interviews were carried out with the participating families. An additional 50 interviews were

conducted in four villages beyond the monitoring sites (Figure 4-1). At each farm, the respondent was selected as the first willing individual sighted on the farm of age > 10 years. Interviews were conducted in local languages (rutoro or rukiga) by the field assistants who used the same introduction and series of questions throughout. The author was present in one in five interviews but played a supporting role only. Each interview lasted roughly one hour. Because we encouraged discussion and questions, answers were interspersed with commentary on a large array of subjects (see Appendix 1 for complete list of questions). Questions on key subjects were asked as follows:

Naming worst pests. *Do animals come to your farm to eat crops? What animals come? What is the worst animal?*

If an individual stated that animals came to her/his farm to eat crops, she/he was then asked to list the animals, and then identify the worst animal. If the farmer could not identify a single worst animal, the order in which she/he listed worst animals was recorded, and the first mentioned was considered the worst in subsequent analyses. Note: the word for animals (*ebisoro*) does not include birds, therefore the frequency with which people complain about birds is potentially underestimated.

Describing the problem and identifying defensive strategies. During an interview, the field assistant asked how recently animals had damaged crops, what crops were most often damaged, if the problem was getting better or worse, and what defensive strategies the farmer and her/his neighbors used. If the respondent mentioned the government in conjunction with the problem, she/he was then asked how the government should be involved in dealing with the problem.

Variables potentially influencing perceptions of the problem. Interviewers recorded the respondent's tribe and length of residence on the farm. Employment with Kibale was recorded if any family member earned wages during the past 5 years with the Ugandan Forest Department, Ugandan National Park Service, the Makerere University Biological Field Station, or any tourism venture.

A farm's distance to the forest boundary was measured in meters using a hip chain at the farm's point closest to the forest. Farm size for the 95 farmers participating in the monitoring exercise was measured through detailed mapping at a resolution of 250 m^2 (for detailed methods see Chap. 3). For the interviews in the additional fifty farms from other sites, farm size was estimated by pacing the length of the farm, and estimating size to the closest half hectare. Three categories were defined, small (< 0.5 ha), medium (0.5-3 ha), and large (>3 ha). An individual's affluence was estimated based on indicators of wealth identified in participatory rural appraisal exercises. Each wealth indicator is ascribed a point value depending on its status relative to other indicators according to local opinion. For example, participants unanimously agreed that owning a tea plantation is a sign of great wealth, while owning small livestock requires only a modest investment. Wealth indicators and their point values were determined as follows: owning a tea plantation = 5 points, employing laborers = 3 points, owning a coffee plantation = 2.5 points, owning cattle = 2 points per ten animals, owning a tin roof = 2 points, owning small livestock (poultry, pigs, goats) = 1 point per ten animals.

Perception of local benefit from Kibale National Park. *Why is Kibale Forest being protected? Who benefits from Kibale Forest? Do local people*

benefit from Kibale Forest?

Individual attitudes toward Kibale National Park are a complex mix of affect and cognition that ultimately cannot be precisely ascertained (Heberlein, 1981). Rather than ask people directly whether or not they supported the park, they were instead asked to describe why they thought Kibale was being protected, whom they perceived to be benefiting, and finally, if local people derived benefits from the Park. If an individual confirmed that local people benefited, the interviewer then asked her/him to describe the benefits.

Finally, during the period the interviews were undertaken, Kibale was upgraded by governmental decree from a forest reserve to a national park. Respondents were asked if they were aware of the change, and if so, what were their thoughts about it.

Results

Patterns of Crop Damage by Animals around Kibale National Park

Among the assemblage of wildlife species present in Kibale are species notorious for their crop damage elsewhere in Africa. Two years of data on damage to 95 farms at six sites around KNP revealed seventeen different species of vertebrates damaging crops (Tables 3-1 and 3-2). Redtail monkeys (*Cercopithecus ascanius*) were the most frequent forager on crops around Kibale's edge, followed by livestock (cattle and goats), and baboons (*Papio cynocephalus anubis*). Comparing the amount of crops damaged by each animal reveals a different order: baboons, followed by elephants (*Loxodonta africana*) and redtail monkeys. Damage by rodents (other than the crested porcupine) was not measured because a) the focus of this study was on

medium to large (>2 kg) vertebrates, and b) farmers complained of rodent damage primarily on harvested and stored food, not on standing crops.

Elephants cause greater damage in a single event than do any other animals (mean=874 m^2, sd= 1530, max=6510 m^2: Table 3-1). The large standard deviation in amount of damage per event reveals that farmers face an unpredictable, and potentially catastrophic loss to elephants, whereas the smaller standard deviation for redtail monkeys, indicates that redtails raid frequently and damage crops in predictably small amounts.

Over 90% of all damage by wildlife occurred within 160 m of the forest boundary (Figure 3-3: range = 0-500 m). This does not indicate that no damage occurs at greater distances. On one occasion, elephants were observed damaging crops at a farm 2 km from the forest, where the farmer reported that this was the first elephant raid in over 58 years. However, proximity to forest is a strong predictor of crop loss to large mammals. This is typical of a situation where there is an island of natural habitat in a matrix of densely settled agriculture (Bell 1984*a;* Hawkes 1991; Kanuhi 1995).

The most preferred crop differed for each of the five most frequent crop raiders (Table 3-3). Chimpanzees and redtail monkeys damaged banana fields with greater frequency than predicted by crop availability. Baboons and bushpigs targeted maize and cassava, two staple food crops of great importance to local farmers (Table 3-3). (Note: for details on measurement of crop preference see Chapter 3).

The amount of damage varied by crop and was positively skewed, i.e., most fields suffered little damage, but some were damaged heavily. Among fields lying within 500 m of the forest boundary, cassava fields on average suffered 7% damage by area to wildlife (n=62 fields, sd=19.5, range=0-100),

bananas fields on average lost 4% (n=56 fields, sd=7.2, range=0-44), and maize fields, 6% (n=151 fields, sd=14.5, range=0-100).

Perceptions of Crop Loss, Ranking of Worst Animal, and Defensive Strategies

Eighty-seven percent of the respondents answered that animals raided crops on their farm (n=145). The average distance of the farm from the forest was significantly higher for those responding that no animals raided their crops (yes to crop raiding, x=167.4 m ± 213.6, 0 to 1000 m; no crop raiding, x= 345.8 m ± 298.1, 0 to 1200 m, t=3.2 one-tailed, p=0.0017). For those farmers whose property lay directly on the edge of the forest, 98% reported crop damage to wildlife (n=55). The average time elapsed since the last raiding event was reported to be 52 days (sd=186.2); this increased with distance from the forest (n=120, tau=0.17, p=0.0072). The average for farms on the edge of the forest was reported to be 15.2 days ± 28.7 since the last raid. The majority of farmers perceived the problem to be getting worse (85%, n=141).

Farmers identified 10 crops as the most vulnerable to damage by wildlife (Table 4-1). Comparing the farmers' rankings of crop vulnerability to the actual events suffered by the crop, the farmers' perceptions did not correspond closely to the frequency of crop damage. *Musa spp.* cover 64% of farmland (fallow excluded) and 70% of events were on bananas, yet only 15% of the farmers described it as the most vulnerable crop. Maize was most often described as the most vulnerable crop (38% of respondents), and indeed this crop suffered damage approximately twice as frequently as expected from the area planted. Despite only 4% of raiding events targeting sweet potatoes, they were ranked second most vulnerable. Men complained more frequently

Table 4-1: A comparison of perceptions of crop vulnerability with actual crop losses.

Crop	Perceived most vulnerable crop*	Perceived Rank	Raiding events (N=2536)	Events Rank	% Area planted**
maize	37.6%	1	15.0%	2	8.0%
sweet potato	20.4%	2	3.6%	4	4.0%
bananas †	15.1%	3	70.0%	1	64.0%
cassava	9.7%	4	5.0%	3	5.0%
millet	4.3%	5	0.1%	9	1.0%
yam	3.2%	6	3.6%	4	6.0%
ground nuts	3.2%	6	0.6%	6	2.0%
sugar cane	2.2%	7	0.5%	7	1.0%
beans	2.2%	7	0.7%	5	7.0%
sorghum	1.1%	8	0.3%	8	3.0%

* % of respondents (N=93) answering: 'What crop do animals eat most?'
** % of total area under crops but excluding fallow (N=65 ha)
† includes cooking, brewing and sweet Musa spp.

about damage on brewing bananas, and women about damage to cassava (df=1, X^2=5.92, p= 0.015). Batoro respondents were more likely to identify brewing bananas, millet and sweet potatoes as vulnerable, while Bakiga more often identified maize.

Among individuals reporting crop damage, the most frequently mentioned animals were baboons followed by redtail monkeys and bushpigs (Table 4-2). The animals most often identified as the worst were baboons, followed by bushpigs, elephants, and redtails. Confining the sample of respondents to those whose farms were monitored, it is possible to compare perceptions with systematic data regarding the frequency and amount of crop damage (Table 4-2). Assigning blame to animals corresponded most closely to the amount of crop lost, rather than the frequency of events. No individual described goats or cattle as the worst animals, despite the fact that livestock are the second most frequent crop raiders and cause 11% of all damage. Bushpigs were blamed more often than the measured damage would predict, while redtail monkeys were blamed less often (Table 4-2). Elephants were ranked third, despite causing more damage than bushpigs. This is likely to be due to the localized nature of elephant crop raiding behavior (Chap. 3). Only eight of the 95 monitored farms suffered elephant damage.

By comparing damage by species versus complaints of worst animal at the level of an individual farm, one avoids the confounding effects of intersite variability. At seven farms out of thirty, livestock were responsible for the greatest number of crop raiding events, and at four of these, livestock caused the most damage (n = 30), yet no farmer complained of crop loss to livestock. Excluding livestock from the analysis, 55% of the farmers

Table 4-2: A comparison of farmers' perceptions of worst animals with systematically measured crop loss around KNP.

Animal Type	Complaints*	Farmers' rankings Worst Animal**	Monitoring Data Most Frequent†	Monitoring Data Most Damage††
baboon	86	1 (36%)	2 (9.4%)	1 (24%)
redtail monkey	84	4 (10%)	1 (51%)	3 (15%)
bushpig	83	2 (28%)	3 (8.5%)	3 (15%)
elephant	32	3 (14%)	7 (1.5%)	2 (21%)
chimpanzee	20	6 (1%)	4 (6.1%)	4 (7%)
rodent	9	5 (2%)	-	-
bird	9	-	-	-
palm civet	3	-	6 (1.7%)	6 (1%)
vervet monkey	4	6 (1%)	5 (4.4%)	5 (2%)

* # of responses to the multiple response question: 'What animals feed on crops in your farm?'

** N=95 respondents
† N=2286 events
†† N=12.4 ha damaged

accurately identified the wildlife species causing the most measured damage (n=30). The discrepancies between reported damage and measured damage reflects an underestimate of redtail monkey damage, and the overestimate of bushpig damage. Thus, this fine-grain analysis yields similar results to the aggregate analysis of 95 farms; to reiterate, livestock damage is not identified, redtail monkey damage is underestimated and bushpig damage is overestimated.

Men complained more frequently about elephants than did women (X^2=21.1, p=0.047). Batoro farmers complained more about elephants, while Bakiga described baboons as the worst pests (df=6, X^2=18.7, p=0.005, n=125). (Note: although few farms were damaged by elephants, both Bakiga and Batoro farmers were affected). Individuals owning large farms more often complained about baboons (Kruskal-Wallis H=10, p=0.007), while small farm owners complained more often about redtail and vervet monkey damage (H=7, p=0.031). More affluent farmers were more likely to rank baboons (tau= 0.22, $p < 0.0001$) and chimpanzees (tau= 0.17, p= 0.003) high on their list of enemies. (Note: affluence and farm size are correlated: H=20.08, $P<0.0001$).

Eighty-five percent of respondents reported using a defensive strategy (n=145). By far the most frequently identified defensive strategy was guarding (78%), followed by fencing (3.4%), trenches (1.4%), trapping (1.4%), and poisoning wildlife (0.7%). When asked who in the family was responsible for guarding, respondents answered men (60%), children (43%), and women (39%) (multiple response question, n=145).

When asked what strategies other farmers use, guarding was again most frequently mentioned (93%), and the frequency of trapping and using poison increased slightly (combined 5%: n=141). Farmers may have been

reluctant to admit to killing wildlife as it is illegal. During the monitoring exercise, traps or poison were encountered on 15% of farms (n=95).

Respondents stating that the government should offer farmers assistance in dealing with the problem of crop loss would ask for help with guarding (70%), compensation for crop loss (30%), fencing off the park (23%), killing animals (9%), and/or buying land from farmers (5%: n=131, multiple response question).

Local Perceptions of the Benefits of Kibale National Park

When asked why Kibale was being protected, 56% of respondents identified wildlife protection as one reason, 40% believed Kibale was for government profit, 35% felt Kibale protected rainfall, 25% believed Kibale was for tourism, 10% for research, 6% for the profit of foreigners, and 10% did not know (n=145, multiple response question). Respondents answered that benefits of Kibale accrued to the Ugandan government (51%), Ugandans in general (49%), foreigners (33%), local community (22%), employees of Kibale (21%), and researchers (15 %) (n=145, multiple response question). When asked specifically whether local people benefit from the park, 84% answered yes, 10% no, and 6% did not know (n=145). The most frequently identified local benefit was fuelwood (44%), building material (28%), potable water (26%), employment (13%), medicine (11%), handicraft materials (7%), rainfall (5%), and 10% saw no benefit. Neither sex, tribe, years of residence, distance from the forest, employment with the forest, nor affluence influenced whether or not an individual identified local benefits of Kibale. However, if an individual complained of elephant damage most, he was more likely not to perceive any local benefits of Kibale (Table 4-3: n=99, X^2=27.37, p= 0.0003).

Table 4-3: Perception of local benefits of KNP as influenced by wildlife conflict.

Worst Animal°	Do local people benefit from Kibale Forest? Yes	No
Baboon	36	1
Bushpig	22	3
Chimpanzee	2	0
Palm civet	1	0
Rodent	2	1
Redtail	13	1
Vervet	0	1
Elephants	7	9
Total	83	16

° Responses to the question: 'What is the worst animal that comes to your farm?'

Finally, when individuals were asked for their response to the news of Kibale becoming a national park, 50.3% were concerned this would result in more crop raiding, 40.7% feared an increase in dangerous animals, 24.8% predicted no change, 22.8% worried about eviction from their land, 6.2% expected more tourists, 6.2% believed there would be fewer jobs available, and 4.1% hoped for more employment opportunities.

Discussion

The disparities and congruences revealed in the comparison of perceptions of crop loss with systematic measurement of damage merit discussion, first, in terms of how the frequency and magnitude of crop raiding influence perceptions. Subsequently I discuss how social, political, cultural and psychological factors amplify people's perception of risk of crop loss to wildlife in two basic ways: 1) some factors increase the exposure to risk of an individual or community, and 2) some factors limit an individual's or community's capacity to cope with risk. Finally, I discuss how crop loss to wildlife is tied to local perceptions of the purpose and benefits of Kibale National Park, and what this means for efforts to build local support for the park.

Perceptions of Crop Loss Versus Measured Crop Damage

Systematic measurement of crop loss to wildlife over two years revealed that the risk of crop loss to medium or large sized wildlife is confined almost entirely to people living within 0.5 km of the edge of Kibale, and that these individuals lose on average 6 to 8% of their crops (Chap. 3). Yet individuals vociferously complained about the severity of the problem,

even those residing as far as 1 km from the forest. Anger about crop loss to wildlife was expressed most intensely during group discussions. "These animals leave us poor and hungry?...Why should we starve so that baboons may eat?"

The contrast between local perceptions of severity of risk and measured damage can be partly explained by the variation in the frequency and magnitude of crop loss. While the recorded average crop loss for farmers living within 0.5 km of the forest was less than ten percent, seven percent of farmers lost more than half of their planted maize and cassava. In other words, local perception of risk may reflect extreme damage events, not average losses.

Perceptions oriented toward extreme events versus average losses may also explain why farmers complain less about redtail monkeys and smaller animals, than about large animals: these animals will not destroy an entire field in a single raid. Eighty monitored farms suffered damage by redtails, yet only 10 farmers described redtails as worst animals (n=95). Baboons damaged crops on 60 farms, and were named worst by 34 farmers (n=95). Similarly, bushpigs damaged 51 farms, and were named worst by 27 (n=95). Finally, elephants damaged crops on only 8 farms, yet 14 farmers reported them as the worst animal (n=95). In sum, the potential extreme damage by a large animal more often shapes people's perceptions than does existing, frequent small losses.

Despite the fact that the majority of damage occurred to bananas, farmers perceive maize and sweet potatoes to be the most vulnerable crops. Again, the potential for total loss may shape local perception more than frequent, small losses. Maize and sweet potato fields are preferred crops of

baboons and bushpigs. On occasion, these animals completely destroyed fields of maize and sweet potatoes, whereas no banana field was ever entirely consumed, not even by elephants. This is due in part to a dramatic difference in field sizes (e.g., maize fields were on average ~1% of the size of brewing banana fields). Another key difference is that, unlike bananas, maize and sweet potatoes have relatively short growing seasons in which an entire field of plants ripen simultaneously (Chap. 5). If damage occurs any time after the first few weeks of growth, a farmer must wait until the next season to replant (Goldman 1986). Thus an entire season's maize production is at risk when baboons enter a field near harvest time.

Losing maize and sweet potatoes is especially significant as they are both staple food crops. A loss of staple crops creates immediate food insecurity (Hill 1993). A loss of cash crops, in contrast, is more likely to create long term insecurity than an immediate crisis.

Factors Shaping or Amplifying Perception of Risk of Crop Loss to Wildlife

Social, political, economic, cultural and psychological factors operating at different levels shape people's perception of risks and solutions (Kasperson et al. 1988; Dow 1992). In this study, farmers' locations with respect to the forest and their individual planting decisions influenced the intensity of risk which they face and, in turn, their own perceptions of the problem. But risk can also be shown to be imposed by members of their own society or by the government. Similarly, coping strategies employed on a farm are constrained by internal and external factors.

Proximity to the forest is the most powerful overall predictor of level of crop damage to wildlife at Kibale (Chap. 3). When we asked farmers

whether they would prefer to live on the edge of Kibale or a farm more distant, their unanimous reply was far away from Kibale's edge. When we asked farmers on the edge why they don't move elsewhere, they answered that land is scarce in the region and more readily available on the forest edge. In group discussions, a consensus emerged that land immediately on the forest edge is generally less expensive than land elsewhere. During interviews and mapping exercises with communities, it became apparent that Bakiga are disproportionately represented on the forest edge, and farms on the edge are more likely to be purchased (versus inherited) than farms elsewhere. These conclusions correspond to the historical account of Batoro chiefs allocating land to immigrants on the outskirts of their settlements, hoping that this would buffer Batoro farmers from crop damage by wildlife (Kabera, in Aluma et al. 1989:27). This risk may be counter balanced with benefits: interview data revealed that Bakiga own larger farms (X^2=44. $p<0.0001$, n=109). Living next to the forest also allows ready access to various resources (Kaipiriri in prep.; see discussion below on perceptions of local benefit of Kibale).

The fact that the amount of labor an individual farmer invested in a certain crop partially influenced his or her ranking of crop vulnerability demonstrates how personal farming strategies with socio-cultural components influence risk and its perception. For example men complain more frequently about banana damage, and women about cassava. Batoro cultivate more brewing bananas and sweet potatoes than Bakiga, and focus disproportionately on damage to these two crops.

Factors Influencing Farmers' Range of Coping Strategies

Farmers coping strategies are constrained and facilitated by factors operating at the individual, community, and societal level. For example, at the individual level, the owner of a small farm near the forest would have serious constraints on his/her coping strategies. Specifically, the owner would have less freedom over the location of planted crops of different palatability. He/she would not be able to plant a large brewing banana plantation between his maize field and the forest edge, a planting strategy observed on most of the large farms around Kibale. Affluent, large farm owners also occasionally used pasture to separate their food crops from the forest edge. These options would not be available to a subsistence farmer with only a small plot and minimal capital. Affluent farmers also have the option to employ others (often others' children) to guard their fields, whereas poorer farmers must either face the risk of crop loss with no guard posted, or sacrifice other opportunities, such as schooling, to have a child vigilant over crops. Ultimately, these passive defense measures (guarding or planting buffers) were considered by most farmers to be costly and only partially effective (see Chap. 3).

Although farmers around Kibale were not observed working communally to defend their crops, an individual's vulnerability was influenced by her neighbors' activities. For example, an individual living in a village where several individuals illegally hunt in their fields suffered lower levels of damage, even if she did not hunt herself (Chap. 3). Ultimately, an individual's best defense against losing his crops to wildlife was to have a neighbor's crops separating him from the forest. This result confirms the logic of the Toro chiefs during the 1940s and 1950s when they

decided to allocate land to immigrant Bakiga farmers on the outskirts of Toro settlements, next to the forest (Kabera, in Aluma et al. 1989). Today large land holders (including Bakiga farmers) take advantage of this defense by renting plots to other farmers immediately along the forest boundary. Researchers elsewhere in Africa have also commented that a densely settled band of farms forms the best barrier to wildlife incursions deep into agricultural land (Bell 1984*a*; Hawkes 1991; Kanuhi 1995).

Beyond individual or communal factors influencing coping strategies, farmers universally complained that their traditional, more aggressive, defensive options are curtailed by the government; specifically, that they cannot kill raiding wildlife, or "chase them deep into the forest." Currently, farmers cannot legally hunt or trap wildlife without formal permission from the Game Department. During meetings and interviews, a fundamental consensus emerged that local defensive options are constrained by the fact that wildlife belongs to the government. This view of wildlife as state property caused considerable resentment (see also Booth et al. 1992). Many farmers bitterly referred to elephants as "the government's cattle." Other animals, such as chimpanzees, were referred to as the property of foreign researchers. "Why should I feed these animals? They are not my animals." This comment reflects the widespread belief that the government is responsible for the problem, and should either help guard, cull animals or build a fence (for a U.S. parallel see Lewis 1988; Conover 1994). When respondents were reminded of the Ugandan government's limited budget and personnel, they suggested that the government should give local farmers the guns to deal with the animals.

The issue of proprietorship explains, in part, why people did not complain about livestock damage. When a goat or cow damages crops, customary law prescribes that the owner of the animal must compensate the victim. In fact, some individuals capture a raiding goat or cow and hold it as ransom until the owner pays for damage. Again and again, in meetings, farmers drew the analogy of the government being a bad neighbor, allowing its livestock to damage crops. On the other hand, during two years of monitoring farms, we observed some of these same individuals frequently grazing their livestock illegally within the boundaries of the park.

The complex interplay of actual risk and effectiveness of coping strategies is filtered through a cultural, social, and economic perspective for each farmer which yields an overall assessment for each farmer of her position or status with respect to the park and its wildlife.

Local Perceptions of the Benefits of Kibale National Park

The majority of respondents were aware of the the official goals of Kibale, including wildlife protection. Their description of the forest as a source of rainfall (35%) is likely to be due in part to an active environmental education campaign (Nganzi 1994). Some believed Kibale existed for government profit (40%), or for the profit of foreigners (6.2%). Similarly, the fact that half of the respondents believed benefits of Kibale accrue to the Ugandan government (51%), reveals a degree of local alienation from the park. Only 22% of respondents initially volunteered that local people benefit from the park. Later, when asked specifically whether local people benefit from the park, the majority responded yes. However, the two most frequently identified local benefits were, in fact, illegal activities (collecting

fuelwood 44%, and building material 28%). In 50.7% interviews, respondents or their family members had earned wages from working with Kibale. Yet only 13% of respondents identified employment opportunities as a local benefit of Kibale. This surprising result was reaffirmed in a group meeting at Kanyasohera, a village with perhaps the greatest number of employees due to its proximity to the field station (65% of respondents at Kanyasohera had employment experience with Kibale). The people complained vociferously about crop loss to wildlife and about being denied access to forest resources. This may be due in part to the fact that forest is most intensely patrolled in the area of the field station. Or, the complaints may derive from 'interview burn out'. Individuals at Kanyasohera had each participated in several previous interviews regarding their attitudes toward Kibale. Hence many farmers were frustrated by the repetitive questions which did not result in any action. During PRA exercises at Kanyasohera, some individuals complained of outrageous injustice by the park as a means of capturing the attention of, or amusing other participants.

A positive attitude toward a protected area or recognition of its goals does not necessarily lead to behavior supportive of its conservation (Heberlein 1981). For example, one individual who stated that Kibale serves an important function protecting rainfall, frequently grazed his cattle inside the park. Other farmers who acknowledged that Kibale served to protect wildlife, set snares or poison bait in their farms for raiding animals. At a broader level, while 56% of respondents understood that Kibale served to protect wildlife, farmers described certain species of animals in negative terms. Baboons were described as crafty and a menace to women and children (see also (Balakrishnan and Ndhlovu 1992; Hill 1993). Many farmers

complained that baboons uprooted crops purely to be malicious (it is likely the baboons were appraising palatability: (Horrocks and Baulu 1988). Chimpanzees were described by some as rapists or thieves. Bushpigs were resented due to their nocturnal raiding habits which caused a loss of sleep for people guarding fields. Elephants were also nocturnal raiders and much feared as smart, dangerous animals capable of killing humans (*ebisoro kalyabantu*, literally, human-eating animal). Over 200 people were killed by elephants in Kenya in 1994 (Newsweek, September 1995). These comments do not represent universal attitudes of local residents toward wildlife, however they do cast doubt on the likelihood of local people being champions of wildlife protection under current circumstances.

Managers of Kibale National Park who are attempting to improve relations with local residents and build local support face several challenges. The news of the elevated conservation status of Kibale revealed the primary sources of anxiety for the local population: crop loss to wildlife, human-wildlife conflict, and eviction from land. Complaints of crop loss are likely to continue, especially if Kibale's elephant population recovers its previously high numbers. Presently, people who suffered crop loss to elephants were likely to perceive no local benefit of the park. This indicates that where elephant raiding is frequent, the costs of living near Kibale outweigh benefits.

Managers receiving complaints about elephants and other animals may be better equipped to define appropriate management responses if they understand the nature of local perceptions regarding crop raiding: (1) perceptions apparently reflect potential, future maximum events more than sustained, frequent current losses, (2) people perceive larger animals as worst pests, often in contrast with actual damage which may be caused by small

animals, (3) personal investment in a crop or farming strategy will influence an individual's perception of risk, and (4) present conditions (such as wildlife belonging to the state) limit people's coping strategies. They should also keep in mind that proximity to the forest is the strongest predictor of damage, and that the population on the edge absorbs disproportionate amounts of damage.

At a broader level, given that local people perceive their benefits from Kibale to come primarily from using forest resources, they are likely to resist management efforts to constrain their access to fuelwood and building materials. Easy favor among local residents is to be gained if open access to park resources is allowed. However, given that people perceive the park and its wildlife to belong to the government, there is a high likelihood that people would overexploit and degrade resources for short term profit (Ostrom 1990).

The long term challenge is to build a local sense of responsibility and ownership for the park. Promising advances toward long term responsibility and care of wildlife by local communities have been made elsewhere in Africa, primarily in savannah settings and among pastoral peoples (Lewis 1988; Kiss 1990). Similar success at Kibale National Park will be difficult due to high human population densities, ethnic heterogeneity, and the historical pattern of conflict between wildlife and sedentary agriculturalists. However, certain conditions are promising for building legitimate local support for Kibale: a) crop loss is confined to a relatively narrow band of farmers, this offers managers a focus community for their efforts to share benefits, including growing tourism revenue; b) at the park level, elephant damage at Kibale is relatively low compared to other forest sites and no one has been killed by elephants (e.g., Aberdares or Shimba Hills in Kenya: Kanuhi, 1995; , 1992), so again, targeted intervention would be appropriate; c) the current

government of Uganda supports environmental protection and local participation, and park staff at Kibale consider it a priority; and finally, d) the system of local governance (Resistance Councils) promoted by the national government is functioning relatively well in western Uganda, allowing park managers opportunities to negotiate with legitimate local institutions regarding rights and responsibilities to Kibale.

CHAPTER 5

TEMPORAL PATTERNS OF WILDLIFE FORAGING ON CROPS IN A FOREST-AGRICULTURE MOSAIC

Introduction

Wildlife foraging on agricultural crops is typically treated as a management problem and rarely captures the attention of ecologists (Mohnot 1971; Masau and Strum 1984; Sukumar 1989; Ganzhorn and Abraham 1991; Peveling 1992). This is due in part to the perception that it is an aberrant or unnatural behavior, despite evidence that animals have been foraging on crops for centuries (e.g., Africa:Vansina 1990; Central Asia: Sukumar 1989; the Neotropics: Donkin 1985). Today, as agriculture expands and encircles wild habitats, wildlife will encounter crops and exotic species with increasing frequency. The ways in which various wildlife species use or avoid crops deserves attention not only as a management concern, but also as a key to understanding how animals respond to variation in quantity, quality, and accessibility of food on a landscape level.

Wildlife foraging on crops has been described by behavioral ecologists as a high risk, high gain strategy (Sukumar 1989). Animals foraging in farms face an elevated risk of being hunted, trapped, or poisoned, but they also gain access to highly nutritious cultivars of lowered toxicity (Sukumar 1989; Ganzhorn and Abraham 1991). The importance of crops in wildlife diet is highly variable by species and location. Examples from the literature describe a continuum of

wildlife dependence on crops. Some species never eat crops or turn to crops only when wild foods are scarce (Laurie in Milton, 1980). Other species forage on crops whenever crops are available or in a preferred stage of maturity (Sukumar 1989; Baranga 1993).

Examining the temporal pattern of wildlife crop foraging in comparison with the temporal availability of wild and cultivated foods sheds light on wildlife foraging strategies in a forest/agriculture mosaic. Food availability in this mosaic is complex and likely to be affected by climate, the phenology of wild vegetation, and the planting strategies of farmers, etc. Thus, it is difficult to decipher whether wildlife are tracking resource availability inside or outside natural habitats, or both. Separating the effect of wild food availability from crop availability on foraging behavior is especially difficult in highly seasonal environments where all plant phenologies and animal behavior are constrained by climatic conditions. At such sites, it is not surprising to find marked peaks in raiding behavior strongly correlated with rainfall (Bell 1984*a;* Litoroh et al. 1992; Osborn 1993). On the other hand, temporal peaks in crop damage also occur in less-seasonal tropical, evergreen environments where they are more difficult to explain (e.g., elephant damage on oil palms (*Elais guineensis*) in Malaysia: Blair 1979).

In a setting where crops are continuously available, and where forest food availability varies significantly over time, an opportunity exists to compare wildlife foraging on crops to forest food availability. The results reveal whether specific crops are more attractive than wild foods or whether specific animals exploit crops when attractive wild foods are scarce. Crops which are eaten whenever they are available may be regarded as more attractive, considering the quality of the food and the risk run in obtaining it, than the majority of wild

foods. In contrast, those crops which are consumed in inverse proportion to attractive wild foods may be regarded as less attractive than wild foods, or alternately, may be the most attractive foods when wild foods are unavailable.

In this paper, the temporal pattern of foraging on crops by five wildlife species (elephant, *Loxodonta africana africana*, bushpig, *Potamochoerus sp.*, redtail monkey, *Cercopithecus ascanius schmidtii*, olive baboon, *Papio cynocephalus anubis*, and chimpanzee, *Pan troglodytes schweinfurthii*) is examined over two years at Kibale National Park, Uganda.

Kibale offers an exceptional opportunity to decipher the foraging strategies of wildlife targeting crops due to the fact that: a) over 30 types of crops are planted around the forest, of both aseasonal and seasonal varieties, including fruit, grain, pulses, pith, and tubers, b) food availability within the forest is subject to intense study, and c) food availability within the forest has marked peaks not tied to rainfall.

After first identifying crops eaten by each of five wildlife species, I examine the frequency with which each species forages on crops, and compare the inter-month variability split by both crop and wildlife species. Processes which are large-scale such as rainfall may lead to correlations between the timing of crop foraging by different species of animals, thus I use inter-specific comparisons as the first step towards identifying large-scale processes shaping the animals' behavior. Then I determine whether variation in the frequency of crop foraging correlates with rainfall and/or the availability and phenology of crops. In the case of the three primates (redtail monkey, olive baboon and chimpanzee), I also test for correlation between the frequency of crop foraging, plant part consumed, and fruit availability in the forest. Results from these

analyses yield insight on the determinants of crop foraging and the probability for wildlife survival in increasingly agricultural landscapes.

Study Site

Kibale National Park (Figure 1-1) is a 766 km^2 remnant of mid-altitude forest, that up until the colonial period, extended south to the Rwenzori Mountains and the Virungas, and west to Zaire (Osmaston 1959). The exceptional diversity and density of wildlife at Kibale (and primates in particular) is thought to derive from the geographic position of Kibale and the mosaic of habitat types it contains. This mosaic is shaped by edaphic, climatic and anthropogenic forces, and includes closed-canopy forest, secondary forest, colonizing bush, grassland, and swamp (Struhsaker in press).

Beyond Kibale's boundaries, forest has been largely converted to agriculture, due in part to the tripling of the region's human population in the past three decades (World Bank 1993). Currently, 54% of land within 1.0 km of Kibale's boundary is used in small holder agriculture (Mugisha 1994). These agriculturalists plant a mixture of over 30 species of subsistence and cash crops; among these, bananas (*Musa spp.*), maize (*Zea mays*), beans (*Phaseolus vulgaris*), yams (*Dioscorea spp.*) and cassava (*Manihot esculenta*) cover the greatest area (Naughton-Treves, unpub. data).

Within this diverse farming system, various wildlife species forage on crops, resulting in much frustration and resentment among local cultivators (Forbes 1991; Edmunds 1994).

Crop Loss to Wildlife

Seventeen species of animals have been recorded damaging crops around Kibale (Chap. 3). However, five species are responsible for more than 90% of the crop damage (excluding that caused by livestock).

Olive baboons are characteristic inhabitants of forest edge environments, and often farmlands adjacent to natural habitat (Rowell 1966; Else 1991). Baboons are the most widespread crop foragers among Old World primates (Else 1991). Despite being considered the worst crop-raiding animal by local agriculturalists (Chap. 4), baboons have not been the subject of long-term study by field biologists working at Kibale. Although the ecology of Kibale baboons is poorly known, some data on their diet is available (Wrangham et al. 1991). Fecal analysis revealed that consumption of non-fig fruits tracked availability, but fig consumption did not (Wrangham et al. 1991). A study of baboons inhabiting a gallery forest in western Uganda, revealed their home range was 3.8-5.12 km^2, and mean day range was 2 km (maximum: 6.4 km: Rowell 1966). Rowell (1966) described olive baboons as forest animals that make risky sorties to forage in adjacent savanna habitat (Rowell 1966). These west Ugandan baboons were mainly herbivorous and supplemented their diet with animal prey (Rowell 1966).

Redtail monkeys are another characteristic inhabitant of forest edge environments and farmlands adjacent to natural habitat (Butynski 1984; Thomas 1991; Baranga 1993). The genus includes other species (*C. aethiops*, *C. mitis*, *C. lhoesti*) notorious for feeding on crops elsewhere in Africa (Kavanagh 1980; Else 1991; CARE 1994). Redtail home range sizes were measured as 0.2 to 0.24 km^2, and day range averaged 1.5 km (0.9 to 2.7 km: Struhsaker and Leland 1988) in groups which did not use agricultural areas. A study of redtails foraging only

within the forest at Kibale revealed their diet was composed of 44% fruit, 22% invertebrates, and 16% leaves (Struhsaker 1980). Among the wild plant foods most frequently consumed by redtail monkeys are *Celtis durandii*, *Chyrosphyllum gorungosanum*, *Funtumia latifolia*, and *Ficus spp.* (Treves, unpub. data).

Chimpanzees demonstrate variable habitat preferences, but appear at highest densities in forested environments (Moore 1992). The home range of one chimpanzee community at Kibale has been measured at a minimum of 7.8 to 14.9 km^2, not including farmland (Chapman and Wrangham 1993). Day range lengths at Kibale are not yet known, however at Gombe, the median day range was 3-4 km for males and 2.7 for females (Wrangham 1977). During 101 hours of systematic observations, the diet of chimpanzees at Kibale included 72% arboreal fruits and 18% terrestrial pith and leaves (Wrangham et al. 1991). Three trees (*Pseudospondias microcarpa*, *Mimusops bagshawei* and *Uvariopsis congensis*) are particularly important food sources for chimpanzees at Kibale and strongly influence their ranging and association patterns (Chapman and Wrangham in prep.). In an analysis of chimpanzee dung, *Mimusops bagshawei* bore a negative correlation with fiber in chimpanzee dung (Wrangham et al. 1991). During periods of fruit scarcity, chimpanzees increase the diversity of their diet and consume a more fibrous diet (Wrangham et al. 1991). The previous authors suggest that dental and gut adaptations of chimpanzees permit them to exploit fibrous foods more effectively.

Elephants inhabiting the forests of E. Africa frequently use adjacent grasslands and savannas (Reuling et al. 1992). Historically, the elephants of western Uganda moved regionally in response to the availability of water and/or grazing resources (Wing and Buss 1970). When fruit availability and foliage density was low in Kibale, elephants moved south toward the savannas

of Queen Elizabeth National Park (Wing and Buss 1970). Present movement patterns are poorly understood, but are likely to be constrained by dense human settlement around Kibale. Their foraging patterns appear to be patchy, as some habitats are utilized with disproportionate intensity (Nummelin 1990; Struhsaker in press). The current elephant population is crudely estimated at 300 individuals which is substantially lower than estimates of 500 to >600 during the 1960s (Wing and Buss 1970; Nummelin 1990; Chapman et al. 1992). The elephants of Kibale have a long history of damaging timber stock, nurseries, and crops in the surrounding area (Osmaston 1959).

Bushpigs are known to cause significant crop damage throughout much of Africa (Goldman 1986; Hill 1993; Vercammen et al. 1993), yet little is known of this elusive ungulate (Kingdon 1979). In fact, debate exists even over the identity of the species present in Kibale; *P. larvatus hassama* (Grubb 1993; Vercammen et al. 1993) versus *P. porcus* (Ghiglieri et al. 1982). Conversion of forest to a secondary scrub/agriculture mosaic results in elevated numbers of bushpigs (Estes 1991; Vercammen et al. 1993). However, complete removal of bush or natural habitat eliminates bushpigs which require cover to survive in agricultural landscapes (Goldman 1986; Vercammen et al. 1993). In the absence of human disturbance, bushpigs are predominantly diurnal, but become nocturnal in agricultural environments (Vercammen et al. 1993). No data exist on ranges in Kibale; in southern Africa home range was estimated to be 0.2-10 km^2 (Skinner et. al in Estes, 1991), and average daily movement was 3 km (0.5-5.8 km) (Seydack in Vercammen et al. 1993). Bushpigs are omnivorous (Estes 1991). Descriptions of bushpig diet at two sites in Kibale include fallen fruits (*Chrysophyllum albidum* , *Parinari excelsa* , and *Mimusops bagshawei*), and the tuber-like root of *Palisota schweinfurthii* (Ghiglieri et al. 1982).

Food Availability Inside the Forest

Kibale experiences two dry and two rainy seasons each year. Interannual variation in the onset of the rainy season and supra-annual cycles contribute to unpredictability, however, each year rainfall typically increases during March through May, and again August through November (Struhsaker in press). Variability in rainfall appears to bear no relation to fruit availability within the forest (Wrangham et al. 1991; Struhsaker in press). However, lack of seasonality does not signify uniform food availability. The fruit of fig trees is available almost constantly while non-fig fruits have peaks which are not related to any known annual cycles (Wrangham et al. 1991). Intraspecific synchrony of fruiting occurs in several species and results in localized fruit abundance (Chapman et al. in prep.). In two species, *Uvariopsis congensis* and *Celtis durandii*, fruiting synchrony was observed between trees up to 12 km apart (Struhsaker in press). The majority of species studied, however, show little or no inter- nor intra-specific synchrony (Struhsaker in press).

The variable pattern of fruiting is also observed in the duration of fruiting events by individuals and species. In *Parinari excelsa*, the duration of a single tree's fruiting event varied between one and 39 months (Struhsaker in press).

Food Availability Outside the Forest

The great interannual variability in rainfall at Kibale precludes the precise definition of planting seasons. Local farmers generally follow a two-season planting regime each year, corresponding with the onset of rains in March and again in late August. However, in an environment with unpredictable year-to-year variability (Struhsaker in press), there is considerable risk involved in deciding when to plant, especially for grain crops, such as maize, millet, and

sorghum. Planting too early may result in desiccated crops; too late and seedlings may be drowned. Farmers attempt to cope with climatic variability at Kibale by incorporating flexibility in their planting calendar. Farmers may replant a crop if rains are extensive, or they may manage to squeeze two crop cycles into a single planting season. Not surprisingly, these farmers do not plant crops in precise synchrony with their neighbors. Instead, farmers typically planted within 2 to 3 weeks of each other, while lags of as much as 11 weeks in one season were observed in planting maize.

A second means of coping with unpredictable rainfall is to plant crops such as bananas, cassava, and yams, which grow throughout the year and can be harvested any time after 6 months. Brewing bananas are tended, harvested and distilled year round and cover nearly 60% of the land under small holder agriculture at Kibale. Farmers report that there are no annual cycles of productivity for bananas *Musa spp.*

Predicting Patterns of Wildlife Foraging on Crops

The wildlife of Kibale forage in a spatially and temporally complex environment. However, the general pattern of food availability in and around Kibale provides some clues for predicting wildlife crop foraging behavior.

First, agricultural foods such as *Musa spp.* and tubers are available throughout the year. This leads to the expectation that monthly foraging frequencies for animals which feed heavily on *Musa spp.* and tubers (e.g., chimpanzees and bushpigs) will show a relatively constant pattern. Second, the availability of grain crops, such as maize, is strongly influenced by rainfall. Monthly foraging frequencies on maize are likely to be correlated with rainfall.

Departures from the above two predictions may be a result of various factors, including fruit availability within the forest. In particular, the availability of non-fig fruits, found to influence ranging and behavior of chimpanzees (Chapman and Wrangham in prep.) and perhaps other primates, may also influence the timing of crop foraging. Therefore, crop foraging patterns are likely to covary with foraging patterns on wild food for some individuals, groups, or species. Finally, inter-village variation in the timing and intensity of crop foraging may obscure broader patterns of predictability.

Methods

Monitoring Wildlife Foraging on Crops

Six villages on the edge of Kibale National Park were selected to monitor wildlife foraging on crops (Figure 4-1). A straight-line distance of ~25 km separated the northernmost and southernmost villages (Sebitoli and Nkingo respectively). The northern 5 villages lay within 12 km of each other. At each village, an area stretching 1.0 km along the forest boundary and extending 0.5 km away from the forest edge was mapped onto cells at a resolution of 250 m^2.

For 2 years, each village was visited by two-person teams on a weekly basis and the monitoring area was completely canvassed for crop damage. Animals were only occasionally viewed foraging in farms, therefore it was necessary to rely on spoor, dental impressions in plants, diggings, wadges, and other physical remains to identify the animal causing the damage.

An independent event was defined as all crop damage occurring during a single exit from and return to natural vegetation (see Chap. 3: for determining independence). The amount of damage was recorded by counting damaged

stems of individually planted crops (e.g., bananas, maize, cassava, yams) and converting this to m^2 using average planting densities for each crop. Damage on sown crops (e.g., sorghum, millet, beans) was measured directly in m^2 [Sukumar 1989]. Crop maturity and parts consumed were noted.

Crop preference by animal type was estimated using frequency of independent events on a specific crop as a percentage of total frequency by the animal in question. Significance was assessed using a chi-square analysis based on the area under each crop (spatial availability), corrected for the proportion of time that crops were edible for wildlife during one season (temporal availability).

Analysis of Temporal Variation in Crop Foraging

The analysis of temporal patterns of crop foraging relied on the calculation of monthly frequencies of forays from the forest. Using independent foraging events only (Chap. 3), I calculated the number of events by each type of animal to yield 23 monthly values from July 1992 through May 1994.

One of the villages studied, Nkingo, lay ~25 km south of the northernmost village and over 10 km from the southernmost of the other villages. At Kibale, altitude and temperature gradients lead to vegetation change (Butynski 1990; Struhsaker in press) which may influence temporal patterns and introduced excess variance into an already variable situation (Chap. 3). Therefore, data from Nkingo were examined separately from the 5 northern sites.

Intermonthly variability in frequency of crop foraging was calculated in two ways for each animal species: first, the standard deviation of monthly events was calculated for each animal; second, the values for adjacent months were subtracted to yield a deviation (absolute value) representing the percentage

change in number of foraging events. The mean of these 22 values is an index of month to month predictability, useful for comparing variation in crop foraging frequency for different species.

Having established the overall pattern of foraging events on all crops, the sample was divided so as to distinguish the effects of different crops on monthly patterns. Following the methodology of Chapter 3, the data were separated by events on maize, bananas, and cassava. These three crops represent distinct food sources (grain, fruit, pith, and tuber) preferred by different animals. Moreover, maize is a highly seasonal crop, while bananas and cassava are continuously available. To test for variation in the quality of *Musa spp.* available over time, the diameter at breast height (dbh) and number of stalks of *Musa spp.* were sampled in 10m x 10m plots on a weekly basis for eight months.

Analysis of Rainfall Versus Crop Foraging

The rainfall data used in this study were collected on a daily basis by Chapman et al. (unpub. data) at the Makerere University Biological Field Station. Rainfall (mm) was compared non-parametrically to monthly frequency of crop foraging for each animal on each of the three selected crops. The Kendall rank correlation coefficient (tau) was used to assess significance.

Analysis of Fruit Availability Versus Crop Foraging

Detailed data on fruit availability in the forest within 5 km of 4 villages (Nyabubale, Kanyasohera, Kabucikire, Rurama: Figure 4-1) was being collected concurrently with my study (Chapman et al., unpub. data). Forest fruit availability (FFA hereafter) was recorded in the first ten days of the month by counting the number of fruiting trees in the sampling area of 4.8 ha. As indicated

above, monthly values for *Mimusops bagshawei*, *Uvariopsis congensis*, *Pseudospondias microcarpa*, and *Celtis durandii* were used in analyses. One or more of these four species' fruits form important components of the diets of baboons, chimpanzees, and redtail monkeys. In addition to testing for correlation between FFA and crop foraging during the same month, I tested FFA of the previous month against crop foraging of the current month. This allows for a lag in response to ripening forest fruit.

Tests of correlation were run using the Kendall rank correlation coefficient tau. Significance levels were set at $p<0.05$. Correlation coefficients are compared directly to assess the relative importance of different predictors. Chi-squared tests were used to assess departures from random distributions of events.

Results

Crop Selection and General Patterns of Crop Foraging

Except for elephants, all the animals foraged on crops throughout the year (Table 5-1). Baboons foraged on the greatest variety of crops (15 types), while chimpanzees and redtails foraged on bananas plus three other crops. Some crops were constantly available (e.g., bananas, cassava, yams), while others were frequently, but not always available (e.g., maize, ground nuts, sorghum). Crop preference (Table 5-2) was determined in Chapter 3, based on frequency of independent events by each animal type corrected for availability of each crop. Note that even animals selecting the same crop showed variation in plant part eaten or age of crop when eaten. For example, baboons foraged on maize throughout its life cycle (seedlings, inflorescence, pith, fruit), while redtails targeted maize close to harvest (Table 5-3).

Table 5-1: Months in which crops were eaten by wildlife around KNP between July 1992 and May 1994.

Crops*	baboons	bushpigs	chimpanzees
avocado	°	°	°
bean	Feb,Apr,June,Sep,Nov,Dec	July	°
brewing banana	all	all	all
cassava	all	all	°
eating banana	Jan-Feb,Apr-Dec	Mar	Mar-May,Aug,Oct-Dec
ground nut	Jan,Feb,Apr,June,July	Jan & Feb	°
Irish potato	June & Nov	May	°
maize	all but May	Jan,Feb,Jun-Aug,Oct, Dec	Jan,Feb,Jul,Aug
millet	July	°	°
pumpkin	°	°	°
papaya	Mar,Nov,Dec	°	°
sweet banana	all but Mar	Mar,June-Aug	Jan-Mar,May,Oct-Dec
sugar cane	June,Oct,Dec	°	Feb,June,Aug,Sep,Dec
sorghum	July	°	July
soy bean	Jan	Jan,Feb,July	°
sweet potato	Jan-July,Aug-Nov	Jan-Nov	°
yam	Feb,Sep,Oct, Dec	all	°

* *Persea sp., Phaseolus vulgaris, Musa sp., Manihot esculenta, Musa sp., Arachis hypogaea, Solanum tuberosum, Zea mays, Eleusine coracana, Cucurbita pepo, Carica papaya, Musa sp., Saccharinum officinalis, Sorghum bicolor, Glycine max, Ipomoea batatas, Dioscorea sp.*

° not observed during systematic sampling.

Table 5-1 continued

Crops*	elephants	redtail monkeys
avocado	Mar	°
bean	°	°
brewing banana	Jan-May,Jul,Oct	all
cassava	Jan&Feb	°
eating banana	Jan-May, July	all
ground nut	°	°
Irish potato	°	°
maize	Jan,Feb,Apr,July	Jan-Mar,May-Dec
millet	Jan	°
pumpkin	°	July
papaya	°	°
sweet banana	Jan-Apr	all
sugar cane	°	°
sorghum	°	Aug
soy bean	°	°
sweet potato	Jan & Feb	°
yam	Feb-Apr	°

* *Persea sp., Phaseolus vulgaris, Musa sp., Manihot esculenta, Musa sp., Arachis hypogaea, Solanum tuberosum, Zea mays, Eleusine coracana, Cucurbita pepo, Carica papaya, Musa sp., Saccharinum officinalis, Sorghum bicolor, Glycine max, Ipomoea batatas, Dioscorea sp.*

° not observed during systematic sampling.

Table 5-2: Preferred crops of 5 wildlife species at KNP.

Animal	Top two preferred crops	N*	Plant parts eaten°	Average age of crops in months (mean ± s.d.)
baboon	maize (Zea mays)	99	11% seedling, 7% flower, 83% fruit	1.9 ± 0.9
	sweet potato (Ipomoea batatas)	26	tuber	3.0 ± 1.7
bushpig	cassava (Manihot esculenta)	78	tuber	9.8 ± 3.6
	yam (Dioscorea sp.)	61	tuber	6.2 ± 3.5
chimpanzee	brewing banana (Musa sp.)	122	55% fruit, 45% pith**	na
	sweet banana (Musa sp.)	11	55% fruit, 45% pith**	na
elephant	sweet banana (Musa sp.)	8	shoot, pith*, inflorescence, fruit	na
	cooking banana (Musa sp.)	17	shoot, pith*, inflorescence, fruit	
redtail	sweet banana (Musa sp.)	169	95% fruit, 5% inflorescence	na
	maize (Zea mays)	168	fruit	3.2 ± 0.5

* independent damage events
° % of events in which the specified plant part was damaged.
** pith = fibrous core of banana stems
na= not applicable

Table 5-3: Damage to Musa spp. by plant part and stem diameter.

	Plant Part Damaged (as % of events)				
	inflorescence	fruit	pith	stem dbh° (cm)	N
baboon	0	78	22	7.65 ± 3.0	65
bushpig	0	8*	92	7.73 ± 2.9	29
chimpanzee	0	55	45	9.90 ± 3.2	140
elephant	100**	100**	100**	11.90 ± 2.5	66
redtail monkey	5	95	0	-	600

*bushpig damage to fruit occurred on fallen bunches.
**elephant damage events destroyed all parts typically.
° mean dbh of stems in plantations was 11.7 ± 2.8 cm.

Figure 5-1(a-e) illustrates the variation in monthly frequency of foraging on all crops for each animal. This pattern is significantly non-random for baboons (N=228 independent events, X^2=41, p=0.0077), bushpigs (N=208, X^2=41, p=0.0077), and redtail monkeys (N=1252, X^2=105, p<0.0001). The evidence for non-random distribution of monthly foraging is weaker for chimpanzees (N=146, X^2=31, p=0.1), and elephants (N=34, X^2=33, p=0.065). Large intermonthly variation is a consistent pattern for all of the animals, but is most pronounced for elephants, and least for redtails (Table 5-4).

No animal's monthly foraging frequency on one crop correlated with that of another crop, except among elephants (maize and bananas: n=23, tau=0.5, p=0.0008). Therefore, further analyses will treat crops separately. Partitioning the data by crop and by wildlife species permitted a test of the relationship between rainfall or forest food availability (FFA) and temporal patterns in the animals' forays into crop land.

Foraging Patterns on Continuously Available Crops

Bananas: All animals foraged on *Musa spp.* (brewing, sweet and cooking bananas), but not all species consumed the same part of the plant (Table 5-3). Redtails and baboons consumed banana fruit more frequently than the pith of stems. Chimpanzees consumed pith and fruit in near equal proportions. Distinguishing the exact part of the banana plant consumed by elephants was not possible due to their habit of destroying an entire field by both trampling and eating plants. Intact inflorescences or fruit bunches were often found on the ground amidst stems stripped and split open by elephants. On average, elephants damaged banana stems of sizes comparable to those available as measured in random sampling (df=65, t=-0.5, p=0.11).

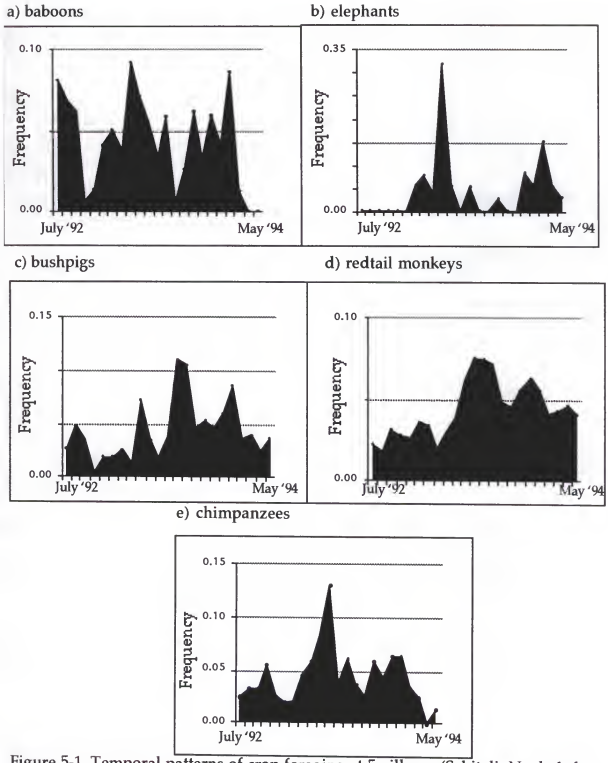

Figure 5-1. Temporal patterns of crop foraging at 5 villages (Sebitoli, Nyabubale, Kanyasohera, Kabucikire, Rurama) around KNP (July 1992-May 1994). Values on the y-axis represent monthly frequencies expressed as a percentage of the annual total of independent events by the animal in question.

Table 5-4: Intermonthly variation in crop foraging events at 5 villages (Sebitoli, Nyabubale, Kanyasohera, Kabucikire, Rurama) around KNP from July 1992 to May 1994.

Animal	N (events)	Intermonthly variation (%) ° mean±s.d.	range	% months absent**
baboons	160*	2.6 ± 1.9	0 - 7.4	8.7%
bushpigs	208	2.3 ± 2.1	0 - 7.2	4.3%
chimpanzees	146	2.2 ± 2.0	0 - 9.2	4.3%
elephants	34	5.4 ± 7.7	0 - 27.8	47.8%
redtails	1252	0.9 ± 0.7	0 - 2.4	0.0%

°° absolute value of the change in monthly % of events as a percentage of annual total.
* a sixth village (Nkingo) was not included (see Methods) but it had similar variation in baboon events (2.9 ± 2.0 %).
** percent of months without damage (N=23 months).

Chimpanzees, bushpigs and baboons damaged significantly smaller stalks than were available (Table 5-3: df=65 in all tests: baboons t=11.7, p<0.0001; bushpigs, t=11.5, p<0.0001; chimpanzees t=5.3, p=0.0001-- in all comparisons, the F test for heterogeneity of variance was non-significant p>0.2).

Wildlife foraging on *Musa spp.* did not vary with rainfall of the same month or the previous month (Table 5-5). Yet, significant correlations occurred between monthly frequencies for different wildlife species (baboons and chimpanzees: tau=0.36, p=0.015; bushpig and redtails: tau=0.33, p=0.028). Correlated peaks in foraging on *Musa spp.* were apparent for the three species of primates (Figure 5-2b). These inter-specific correlations in the timing of *Musa spp.* foraging suggest a forest-wide periodicity; I next tested whether forest fruit availability (FFA) was associated with variation in timing.

Monthly FFA varied as follows: *Mimusops bagshawei* varied from 0 to 7 fruiting trees, *Pseudospondias microcarpa* varied from 0 to 2, *Uvariopsis congensis* varied from 0 to 115 and *Celtis durandii* varied from 0 to 47 fruiting trees (area sampled was 4.8 ha). The previous month's number of fruiting *Mimusops bagshawei* trees showed a significant negative association with frequency of foraging on *Musa spp.* by chimpanzees, baboons and redtail monkeys (Table 5-5). The most significant association was found between the previous month's total number of fruiting *Mimusops bagshawei* plus *Pseudospondias microcarpa* and chimpanzee foraging on *Musa spp.* (tau=-0.48, p=0.0017). The negative relationship between FFA and crop foraging was strongest when a given month of *Musa spp.* foraging was compared to the previous month of FFA (Table 5-5).

When *Musa* foraging events by baboons were split by consumption of fruit or pith, the negative correlation with FFA was significant only for fruits (n=23, tau= -0.39, p= 0.012). The opposite was true for chimpanzees, in that only

Table 5-5: Correlations between crop foraging frequency and rainfall or forest fruit availability (FFA).

	Predictor variables (values represent tau correlation coefficients)									
	Same month (N=23)					Previous month (N=22)				
	rainfall°	FFA				rainfall°	FFA			
		uva°°	mim	psd	C.d.		uva°°	mim	psd	C.d.
maize foraging										
baboons	-0.37*	-	-	-0.33*	-	-0.39*	-	-	-	-0.35*
bushpigs	-0.36*	-	-	-	-	-	-	-	-	-
chimpanzees	-0.46**	-	-	-	-	-	-	-	+0.38*	-
elephants	-	-	-	-	-	-	-	-	-	-
redtail monkeys	-0.32*	-	-	-	-	-0.48**	-	-	-	-
brewing banana foraging										
baboons	-	-	-0.31**	-	-0.31*	-	-	-0.42**	-	-0.35*
bushpigs	-	-	-	-	-	-	-	-	-	-
chimpanzees	-	-	-0.35*	-	-	-	-	-0.38*	°°°	-
elephants	-	-	-	-	-	-	-	-	-	-
redtail monkeys	-	-	-0.25*	-	-	-	-	-0.36*	-	-

° rainfall measured as monthly precipitation (mm) taken from Chapman et al. (unpubl. data)
°°monthly # fruiting trees uva= Uvariopsis congensis mim= Mimusops bagshawei
psd= Pseudospondias microcarpa C.d.= Celtis durandii

- : no significant association (p>0.05)
* significance level: 0.05 ≥ p > 0.01
** significance level: 0.01 ≥ p > 0.001
°°° combining mm with psd (tau=-0.48, p=0.0017)

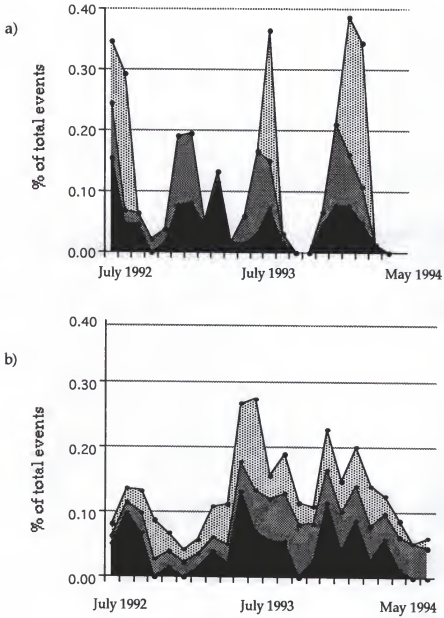

Figure 5-2: Monthly frequencies of crop foraging by primates around KNP. Monthly averages (y-axis) are expressed as a percent of the annual total of independent events by each primate: baboons (■), redtails (■) and chimpanzees (▩).
a) maize (*Zea mays*)
b) bananas (*Musa spp.*)

pith consumption was correlated negatively with forest fruit availability (n=23, tau= -0.49, p=0.0018). The correlation between chimpanzees and baboons in the timing of their forays on *Musa spp.* was due to fruit (tau=0.53, p=0.0007) rather than pith (tau=0.06, p>0.5).

Regarding cassava, bushpigs, baboons and elephants were the only ones to eat this crop and no association with FFA or could be detected.

Foraging on Seasonal Crops

Maize: Foraging by wildlife on maize increased in the months following rainfall (Figure 5-3). For all animals except elephants, foraging on maize displayed a significant negative correlation with rainfall (Table 5-5, Figure 5-4a). Maize is planted at the onset of the rain, and requires 3-4 months to ripen. Wildlife forage most heavily on maize when it has fruit (Table 5-2), thus the lag between rainfall and damage to maize (Figure 5-3). By comparison, foraging on *Musa spp.* was not correlated with rainfall (Figure 5-4b).

As would be expected, the timing of maize foraging between animals is significantly correlated (n=23 months, baboons and chimpanzees: tau=0.36, p=0.017, baboons and redtails: tau=0.56, p=0.0002, bushpigs and chimpanzees: tau=0.7, p = 0.0001). This was especially apparent among the primates (Figure 5-2a).

Baboons and chimpanzees demonstrated some associations between FFA and monthly maize foraging (Table 5-5). The only positive correlation observed was between the previous month's number of fruiting *Pseudospondias microcarpa* trees and monthly maize foraging by chimpanzees. For baboons, *Celtis durandii* fruiting bore a significant association with both maize and banana foraging

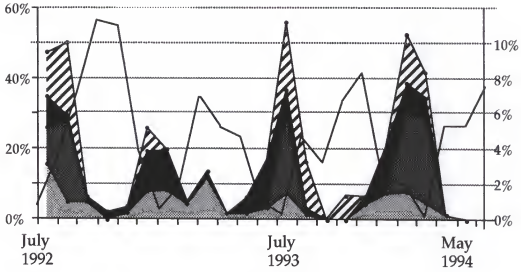

Figure 5-3: Monthly rainfall (narrow line over shaded areas) superimposed on monthly frequency of maize foraging by baboons (▨), chimpanzees (■), redtails (■) and bushpigs (▨). The y-axis on the left measures the number of independent events as a percentage of annual total of independent events for a particular wildlife species. The y-axis on the right measures rainfall (mm) as a percentage of annual precipitation.

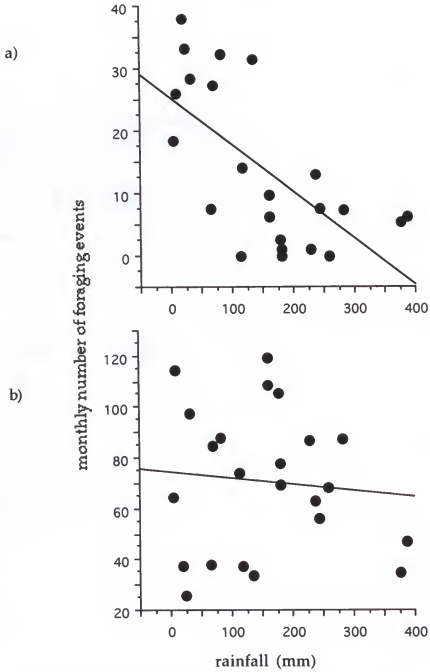

Figure 5-4: The relationship between rainfall and crop foraging events. The x-axis is rainfall (mm) taken from Chapman et al., (unpubl. data) and the y-axis is the number of independent foraging events by baboons, bushpigs, chimpanzees and redtail monkeys (lumped). Regression lines are drawn to facilitate visualization of the relationship. See Table 5-5 for non-parametric tests of significance.
a) maize (*Zea mays*)
b) bananas (*Musa spp.*)

(which are not themselves correlated). The importance of this fruit in the diet of baboons is unknown.

Discussion

This research demonstrated the marked intermonthly variation in the frequency of crop foraging by baboons, bushpigs, chimpanzees, elephants, and redtail monkeys of Kibale National Park. The variation was most pronounced for elephants, and least for redtail monkeys. Baboons proved to be the greatest crop generalists, both by the number of crop species they foraged on, and the crop stage of maturity when consumed. Bushpigs nearly matched baboons in terms of the diversity of crops they consumed. Bushpigs and baboons also share similar levels of intermonthly variation.

Despite considerable variation between the behavior of the wildlife species, two consistent patterns underlay the distribution and timing of crop foraging: Foraging on maize was correlated between most wildlife species, and occurred in negative association with rainfall. The timing of foraging on bananas (*Musa spp.*) bore no relation to rainfall yet monthly frequencies were correlated for several species. This suggests that some large-scale ecological processes other than rainfall influenced the timing of foraging on this continuously available crop. The availability of certain forest fruits was associated with declines in crop foraging. In the case of cassava, another continuously available crop, neither rainfall nor forest fruit availability was associated with patterns of foraging.

Examining the effects of rainfall first, I turned to the analysis of maize foraging by wildlife because a) maize has clear periodicity in availability, and b) maize is a preferred crop of several species at Kibale, as it is of wildlife around

the world (Maples et al. 1976; Milton and Binney 1980; Else 1991; Conover 1994). Wildlife preference for maize may be due to its elevated protein content (dry matter of cob=12% protein) (Sukumar 1989).

The peaks and troughs of availability of maize arise because the majority of farmers time the planting of maize to coincide with the onset of the rains. The farmers' planting strategy (to reduce the risk of drowning seeds while capitalizing on available soil moisture) super-imposed on the phenological characteristic of maize (synchronous ripening of the plants) results in peaks in maize availability. All animals, except elephants, responded to these peaks by feeding heavily on maize. Thus, foraging on maize was negatively correlated with rainfall (again, excluding elephants).

As mentioned above, elephant foraging on maize did not reflect the same seasonal pattern as other animals. This may be an artifact of using an inadequate scale of study to accurately capture elephant crop foraging behavior [Sukumar 1989]. This is discussed further below.

The pattern of wildlife foraging on maize observed at Kibale accords with the most commonly published explanation for crop foraging behavior, that is that animals are drawn out of natural habitat by highly palatable crops which are available according to planting seasons (Greenhood 1971; Marks 1976; Milton and Binney 1980; Bell 1984*a;* Booth et al. 1992; Damiba and Ables 1993; CARE 1994). This explanation focuses on crops as a magnet, influencing animal behavior in isolation from ecological processes occurring within the natural habitat.

Foraging by wildlife on *Musa spp.* revealed a temporal pattern unrelated to rainfall. Except for elephants, all animals foraged on *Musa spp.* throughout the year. However, there were peaks in the frequency of foraging on *Musa spp.* and

the timing of consumption correlated between some pairs of species (baboons and chimpanzees; bushpigs and redtails). Months with heavy Musa foraging tended to co-occur and be preceded by months of low forest fruit availability.

Baboons and chimpanzees have both been observed to consume non-fig fruits in relation to their availability (Wrangham et al. 1991). Chimpanzee ranging and association is partly determined by the fruiting of the tree species examined here (Chapman et al., 1995; Chapman and Wrangham, in prep.). Scarcity of these preferred non-fig fruits led chimpanzees to consume diets with more fiber (Wrangham et al. 1991). No attempt has been made to determine what portion of this fiber derives from *Musa spp.* Because fruit abundance of the previous month proved most effective in predicting *Musa spp.* foraging, it may be that depletion of fruit crops leads chimpanzees and baboons to leave the forest.

Interestingly, chimpanzees and baboons reveal diametrically opposed patterns of *Musa spp.* use. Decline in forest fruit availability led the chimpanzees to increase *Musa spp.* pith consumption, not *Musa spp.* fruit consumption. Baboons, in contrast, targeted the fruit of *Musa spp.* in response to forest fruit declines. This difference may reflect among other possibilities: (a) greater tolerance for unripe fruit among the baboons, (b) further ranging by baboons to seek out the less widely distributed fruit of *Musa spp.*, (c) interspecific differences in the ability to extract pith as a function of stem dbh, and/or (d) hindgut fermentation ability allowing chimpanzees to gain a premium from pith consumption (Wrangham et al. 1991). The use of *Musa spp.* pith by chimpanzees appears to conform to the suggestion that terrestrial sources of forest pith (e.g., *Maranthachloa spp.*: Wrangham et al. 1991) are crucial to chimpanzee survival during periods of fruit scarcity (Wrangham 1986).

The pattern of wildlife foraging on the continuously available *Musa spp.* observed at Kibale reflects an inverse correlation between amount of crop consumed and forest food availability. This insight emphasizes the interconnections between forest and agricultural habitat. For example, a farmer may suffer less crop damage as a result of fruiting events within the forest. Elsewhere animals have been observed to forage frequently on continuously available crops, but to forage less intensively when preferred wild fruits are available (e.g., redtail monkeys on cocoa plantations, Baranga 1993).

Deciphering Temporal Patterns of Elephant Damage

The observed temporal patterns of crop foraging by the elephants of Kibale National Park are likely to be influenced by the placement of study sites relative to the areas the elephants are using during the study period. An underlying premise of this research is that the six kilometers of forest edge spanned by the study sites are sufficient to acquire a representative sample of exit points for wildlife. This may not be the case for elephants as they travel tens of kilometers over the course of days, and appear to have historical exit points (e.g., Sebitoli, see Chap. 2). Separating temporal variation versus spatial variation for an animal foraging at a landscape level is difficult (Sukumar 1989).

The spatial constraints on this study may also have influenced the observation of great intermonthly variability in crop foraging for elephants. Elephants may in fact forage on crops sporadically. Or, they may be foraging beyond the sampling areas of this study. As a counter-example, redtail monkeys were observed to have lower intermonthly variation in crop foraging frequency than the other animals. A possible explanation lies in the fact that they have small home ranges (20-24 ha) which they use intensely (Struhsaker and Leland

1988). In a single sampling grid of 50 ha, the observed foraging behavior by redtails is likely to fully represent that of one or two groups.

Elephants were the only species which displayed a correlation between the timing of their *Musa spp*. consumption and their maize consumption. Crop foraging by elephants did not correlate significantly with rainfall or fruit availability in forest. This relationship suggests three alternative scenarios: (1) elephants leave the forest to eat maize at a different stage of ripeness than other animals, (2) elephants eat and damage maize incidentally as a by-product of foraging on other crops such as *Musa spp*., or (3) elephants leave the forest for other reasons and eat whatever they find palatable.

In Malawi, elephant foraging on crops was judged to be a combination of response to increase in fiber content of wild grasses during wetter season and maize coming into seed (Bell 1984*a*). Bull Asian elephants have been recorded to obtain 9.8% of their diet from crops, increasing to 22-30% during the finger millet season (Sukumar 1989: 122). On the other hand, Sukumar claims that Asian elephants forage on crops even when there is a surplus of natural foods (Sukumar 1989).

Conservation Implications

Today throughout much of Africa and Asia, wildlife survives in patches of wild habitat surrounded by dense human agriculture. Fragmentation leads to increasing edge and decreasing ability of large animals to travel without crossing agricultural areas (Sukumar 1989). In such a setting, terrestrial or semi-terrestrial, omnivorous, edge-favoring, adaptable animals (such as the 5 species of this study) are able to supplement their diet with crop foraging, despite facing elevated risk from human attacks or traps (Horrocks and Baulu 1988; Chap. 4).

Such animals appear to benefit relative to interior specialist wildlife species (Kavanagh 1980). Indeed, even without large blocks of wild habitat, crop foraging species may be able to survive. In one case, a bull elephant residing in a forest patch obtained ~20% of its diet from crops (Sukumar 1989). Other studies have described how some birds (*Quelea quelea*) and monkeys (*Cercopithecus aethiops tantalus*) have even been able to colonize new sites through exploitation of crops (Kavanagh 1980; Peveling 1992). However, the animals' use of or dependency on crops is ultimately detrimental to its survival in that low human tolerance for crop loss typically results in eradication or control operations (e.g., Altmann and Muruthi 1988). Moreover, if natural habitat is eventually entirely replaced by agriculture, extirpation of medium to large sized wildlife is inevitable, even for adaptable omnivores (Southwick et al. 1986).

The apparent negative association between forest fruit source availability (*Mimusops bagshawei* and *Pseudospondias microcarpa* trees) and the timing of foraging on *Musa spp.* fruit and pith by primates offers, at very least, a tool for forecasting damage to Musa plantations.

CHAPTER 6

RECOMMENDATIONS FOR MANAGEMENT AND RESEARCH

Historical and Regional Perspectives on Wildlife Crop Raiding

Recent articles describe human-wildlife conflict as one of the major conservation problems in Africa today (Dublin 1995; Hammer and Contreras 1995; Tchamba 1996). Many conservationists describe human-wildlife conflict as a new problem that has been created by burgeoning rural populations settling within or adjacent to wildlife habitat (Baldus 1988; Balakrishnan and Ndhlovu 1992; CARE 1994; Pitkin 1995). However, human-wildlife conflict at agricultural frontiers in Africa has existed for decades, if not centuries (Osmaston 1959; Graham 1973; Vansina 1990; Booth et al. 1992; Ville 1995). Moreover, the conversion of Uganda's forests to agriculture combined with colonial, problem-animal-control programs and heavy poaching has greatly reduced wildlife-human conflict at the national level. For example, in 1929, elephants ranged over 70% of Uganda (Brooks and Buss 1962), and were considered a threat to agricultural production at the regional level (Graham 1973; Ugandan Game Department archives 1949). Since then, elephant populations have been dramatically reduced, and human-elephant conflict now occurs only in the vicinity of parks and reserves which encompass less than 8% of Uganda (World Resources Institute, 1994).

The current conflicts between farmers and wildlife at the edge of Uganda's parks and reserves echo the traditional pattern of conflict at

agricultural frontiers. In historic times, agricultural frontiers were dynamic. At some sites, shifts in animal distributions or movements forced farmers to abandon cultivation due to heavy crop losses or danger (Osmaston 1959; Vansina pers. comm.). More recently, as problem animals were eradicated, a major constraint on settled agriculture was removed and the frontier expanded (Graham 1973). Today, park edges mark a permanent 'frontier' where wildlife habitat meets agriculture or other human land uses. In sum, human-wildlife conflict itself is not new. What is novel about today's problem is that managers are attempting to maintain substantial wildlife populations adjacent to densely settled agriculture.

The results of this study indicate that the majority of crop damage to medium to large wildlife species (more than 3 kg) is confined to a narrow band of farms lying within 250 m of the forest boundary (Chapter 3). This tight relationship between damage and distance to the park boundary has been reported at other sites where parks are surrounded by dense agricultural settlement, such as Aberdares National Park, Kenya, where the majority of damage occurred within 400 m (Kanuhi 1995).

Almost all farmers residing within 500 m of the forest boundary reported problems with wildlife damage. Across the 96 farms monitored in this area, banana fields suffered, on average, 4% damage by area, cassava fields 7%, and maize fields 6%. However, these calculations of average losses include fields never damaged. For those banana fields which were damaged, one-quarter lost >400 m^2. One quarter of the maize and cassava fields which were damaged lost >10% and >50% of their crop respectively. Moreover, certain villages suffered more intense damage than others (e.g., Nyabubale lost five times more crops than did Nkingo). Such variation between crops,

between farms and between villages is typical for crop raiding at other parks in Africa (Bell 1984*a;* Hawkes 1991; Damiba and Ables 1993; Kanuhi 1995). This variation makes universal management prescriptions difficult, and also hinders efforts to compare the magnitude of the problem between different parks. For example, in Cameroon, elephants damaged <10% to 30% of planted crops around a national park (Tchamba 1996), depending on the type of crop and the village sampled. In Niger, an average of 0.2% damage by elephants was recorded for farmers neighboring a park, yet certain individual farmers lost 100% (Taylor in Tchamba, 1996). Average crop loss to wildlife at a site in Malawi was estimated at 17%, but again, individual farmers suffered from 0% to 100% (Bell 1984*a*).

Confounding comparisons between sites is the different sampling regime of each study. In some studies, particularly where human population density was low (e.g., 49 persons/km^2) and animals migrate regionally, crop damage was frequently recorded several km from the park boundary, and damage levels were estimated over extensive areas (Tchamba 1996). Studies at densely populated sites (e.g., >200 persons/km^2) typically base damage estimates on areas within 1 km of the forest boundary (CARE 1994; Kanuhi 1995).

Farmers around Kibale can reduce their risk of crop loss to some animals by guarding, hunting, and planting less palatable crops or pasture near the forest boundary. Some farmers have managed to increase the size of their farms at the forest boundary by buying more land. This strategy may reduce risk because large farms are less likely to lose an entire season's production due to a single incursion by wildlife. Other farmers have moved away from the forest, or have rented out the most vulnerable parts of their

farms. Most vulnerable are those individuals growing food crops on small farms (<1 ha), near the forest (<250 m), at villages where elephants are common (e.g., Sebitoli).

From a national or international perspective, crop losses of 4-7% in a narrow band of farms appear to be a trivial price for maintaining endangered wildlife and forest habitat. In fact, the zone of heaviest crop loss (250 m beyond forest boundary) could be considered ~3,000 ha of 'extra' habitat for wildlife at Kibale (Mugisha 1994). But living within this 'extra' habitat are ~7,000 frustrated farmers whose attitudes and actions will have a long term impact on the conservation of forest and wildlife at Kibale.

Managers of Kibale National Park receiving complaints about wildlife crop damage may be better equipped to define appropriate management responses if they understand the nature of local perceptions regarding crop raiding: (1) perceptions apparently reflect past or potential maximum events more than steady, small losses; (2) people perceive large animals as worst pests, despite the fact that actual damage by small animals is often greater, (3) personal investment in a crop or farming strategy will influence an individual's perception of risk, and (4) present conditions (such as wildlife belonging to the government) limit people's coping strategies.

Within the zone of greatest crop damage surrounding Kibale, baboons, bushpigs, and redtail monkeys were ubiquitous crop raiders, while elephants caused infrequent, localized, and large scale damage. The localized distribution of crop damage by elephants parallels observations from other sites (Bell 1984*b*; Hawkes 1991; Damiba and Ables 1993; Lahm 1994; Tchamba 1996). People are especially poorly equipped to defend their crops from elephants (Chapter 3). At Kibale, as in many other sites, local residents

perceive large and potentially life-threatening animals, such as elephants, to be the responsibility of the wildlife authorities (Hawkes 1991; Booth et al. 1992).

The government of Uganda is placed in the difficult position of protecting wildlife while guarding the property and lives of its citizenry. Management efforts to minimize human-wildlife conflict around protected areas fall into three general categories: raising public tolerance for wildlife, deterring wildlife from entering crop lands, and killing problem animals. Each of these approaches will be discussed below in the context of Kibale.

Raising Public Tolerance for Wildlife

Local reaction to the news that Kibale was changed from a forest reserve to a national park in 1994 revealed the primary sources of anxiety for the population neighboring the park: crop loss to wildlife, human-wildlife conflict, and eviction from land (Chapter 4).

A variety of strategies have been used in southern and eastern African countries to increase public tolerance for wildlife, including direct monetary compensation, employment opportunities, revenue sharing, environmental education and community management of wildlife. The experience gained in these efforts ought to inform similar efforts at Kibale.

Direct Monetary Compensation

Monetary compensation schemes for crop damage have been attempted on several occasions in East and Southern Africa with poor results (Booth et al. 1992). Such schemes were nearly always abandoned after it was

shown that they (1) were open to abuse or blatant corruption, (2) were cumbersome and expensive to administer, and (3) reduced motives for self defense among farmers (Bell 1984*a;* Booth et al. 1992). Around parks and reserves in Zimbabwe today, monetary compensation is offered only in cases where human life has been lost to wildlife (Murombedzi, J., Project CAMPFIRE, pers. comm.). In the U.S., direct monetary compensation is paid to ranchers who lose livestock to panthers or wolves (Brooke 1996). Yet, even with compensation, many ranchers continue to hold hostile attitudes to wildlife (Riccuiti 1995; Brooke 1996).

Farmers around Kibale still retain hope of receiving compensation for crop loss to wildlife. Offering compensation to all households suffering damage from bushpigs or primates would be difficult because hundreds of households are affected on a regular basis. Victims of elephant damage deserve special consideration, however. They are few in number (currently on the order of 20 families per year on a park-wide basis) and they have minimal options to defend their crops. Complaints about elephants are likely to increase if the population recovers to previously high numbers. Results of this study revealed that people who suffered crop loss to elephants were likely to perceive no local benefit of the park. This indicates that where elephant raiding is frequent, the costs of living near Kibale outweigh benefits. Farmers suffering repeated damage by elephants were the only individuals to report a desire to sell their property.

A plan to directly compensate farmers suffering elephant damage is likely to suffer the same problems experienced in other compensation plans. However, due to the hardship these farmers face, they should receive preferential treatment in indirect compensation schemes, i.e., they should

have priority access to jobs associated with the park or be able to participate in a tourism revenue sharing program. Alternatively, funds should be made available to purchase the farms of individuals who have long suffered elephant damage and who wish to sell their land. This offer would have to be made very cautiously so as not to raise fears of evictions, nor to create inflated land values on the forest edge. Considering that the farms at Nyamigaywa and Kitoma (Sebitoli area) are among those worst hit by elephants, and they lie between a tea plantation and the forest, park managers may want to consider including the tea company in plans to plant tea in areas vulnerable to elephants (see Methods of Deterrence, below).

Employment Opportunities and Revenue Sharing

Increasing economic benefits from wildlife for neighboring populations is celebrated by many conservationists as the best way to elevate local support for conservation (Harcourt et al. 1986; Western 1989; CARE 1994). Around a game ranch in Burkina Faso, local people reportedly "welcome the proximity of the ranch and its elephants" due to the benefits they receive, such as jobs, meat from culling operations, fishing on the ranch and the opportunity to sell local crafts to tourists (Damiba and Ables 1993: 97). Unfortunately, the results of interviews at Kibale were less encouraging. Individuals employed by Kibale were not more likely to identify local benefits of the park (Chapter 4). Without interviews before employment, it is not possible to determine if people changed their perceptions as a result of gaining employment.

Environmental Education and Local Resource Use

The majority of respondents were aware of the the official goals of Kibale, including wildlife protection. This awareness and their description of the forest as a source of rainfall are likely to be due in part to an active environmental education campaign (Nganzi 1994). The fact that half of the respondents believed benefits of Kibale accrue primarily to the Ugandan government reveals a degree of local alienation from the park. Only 22% of respondents initially volunteered that local people benefit from the park. Later, when asked specifically whether local people benefit from the park, the majority responded yes (Chapter 4). However, the two most frequently identified local benefits were, in fact, illegal activities (collecting fuelwood and building materials).

Permitting resource use inside national parks is a highly controversial subject. Several conservationists argue that unless local communities directly benefit by obtaining resources from the park, they will always resent the presence of the park (Western and Pearl 1989). Yet determining the appropriate resources and defining sustainable harvest rates is difficult, as is controlling the actual rates of harvest. Pilot efforts in this direction are ongoing at Kibale related to the harvest of wild coffee, medicinal plants and honey. Meanwhile, local residents extract timber products (firewood, fuelwood for charcoal, and construction material), hunt and graze their livestock in the park illicitly. Legalizing these uses should not be considered until there is better definition of who is allowed access to these resources and with what rights and responsibilities. Opening resource use to the general public at this time, while people believe the park is property of the state, would inevitably lead to over-exploitation of resources (Ostrom 1990). The

long term goal is to match local rights to resources with local responsibility for conservation.

Deterrence of Wildlife

Currently, farmers around Kibale attempt to deter wildlife from their fields by guarding, lighting fires, keeping dogs and hunting (Chapter 3). These methods are only partially effective, and in some cases exact high social cost. The far-reaching ramifications of continual guarding particularly affect children and adolescents, whose education may suffer as they stay at home to guard fields, or who lose sleep or suffer greater exposure to diseases such as malaria from nocturnal or crepuscular guarding.

Further research is needed to quantify the benefits of crop guarding. Although crude, the measures used in this study to quantify behavioral and infrastructure investment in guarding suggest that farmers are responsive to risk (e.g., the positive correlation between guarding and damage for some species). Whether their assessments of risk are followed by effective counter-measures is not definitively shown in this study. However, the farmers' reports, my own observations of wildlife on the edge of the forest and published accounts (Mohnot 1971; Horrocks & Hunte 1986) suggest that animals will flee or avoid intensely guarded fields.

Farmers' reports agreed with research showing that guarding did not intimidate elephants. Again, farmers called on the government to assist them with defending their farms from elephants. The fact that elephant damage is localized suggests that elephant deterrence activities in the near future should be targeted primarily along the northern boundaries of Kibale.

Disturbance Shooting

On occasion, the Ugandan Game Department sends a guard to farms when elephants are present. The guard typically attempts to frighten the elephants back into the forest by shooting in the air. This deterrence is effective only on a temporary basis. Elephants elsewhere have become habituated to this exercise (Booth et al. 1992). For example, in Malawi, plots guarded by above-average densities of hunter units (shooting to scare, not kill elephants) showed no significant reduction in crop damage rates (Bell 1984*a*).

Buffer Crops

Planting less palatable crops near the forest boundary is a logical management option because crop damage is highly correlated with proximity to the forest edge. Thus, while a buffer of unpalatable cultivars providing little concealment is unlikely to stop wildlife incursions all together, it may reduce the damage which occurs when food crops are planted on the forest edge. The current list of buffer crops being considered by managers at Kibale includes: soybeans, sunflowers, tobacco and tea.

Preliminary trials were conducted using soybeans as a buffer. During the first season in which soybeans were planted, minimal damage occurred. By the third season, however, bushpigs damaged a substantial portion of the crop (Naughton-Treves, unpub. data). Ultimately, soybeans were no more effective a buffer than were beans, a crop grown traditionally in the area.

To be successful as a buffer, a cultivar must be profitable, unpalatable and planted over a large enough area to reduce the attractiveness of crops beyond. The majority of farmers around Kibale own small landholdings and do not cooperate with neighbors with regard to crop selection, maintenance

or timing of planting. For example, one farmer at Kibale planted tea immediately on the forest boundary, and planted a maize field just beyond the tea, approximately 100 m from the forest. His tea plantation was small, however (~5000 m^2), and wildlife simply traveled through his neighbor's fallow land and fed in his maize field. Given the small landholdings on the edge of Kibale, a buffer is only a viable option if neighbors collaborate in their planting.

Tea is a popular buffer crop in highland Africa as it is not consumed by any wildlife species (Reuling et al. 1992; Kanuhi 1995). The option of planting a tea buffer merits careful consideration because tea is a profitable crop already in production in the area. However, tea is not a viable crop for small scale farmers because it requires high initial capital investment. Another great drawback of tea is the tremendous volume of fuelwood required for processing. For every 3 ha of tea, one ha of fuelwood is required (Kluge, S., Toro Tea manager, pers. comm.).

The Nyayo tea zone around the Aberdares National Park in Kenya offers lessons. First, a great deal of natural forest was lost when this tea zone was planted within the boundaries of the park (Butynski, pers. comm.). Second, the tea zone has not served as an absolute barrier. Where it is 50 m wide, elephants cross the tea without hesitation (Reuling et al. 1992). Or they use fallow patches within the plantation to cross the larger areas of tea (Kanuhi 1995). In sum, a tea buffer is unlikely to deter elephants unless it is planted continuously and extensively. Such a planting regime is beyond the scope of an individual farmer, and would require collective or industrial ownership.

Electric Fences

Throughout Africa, agriculturalists have proven to be the group of people most adamant about confining wildlife to parks using physical barriers (Seidensticker 1984; Bell 1987; Booth et al. 1992). Pastoralists, on the other hand, worry that physical barriers would impede their access to grazing and therefore are generally less supportive of fences. Considering that sedentary agriculturalists dominate the vicinity of Kibale it is not surprising that the option of constructing fences is locally popular.

Kenyan Wildlife Service authorities recently decided that there was "no option but to erect barriers if substantial wildlife populations, particularly elephant, are to survive in rural areas of Kenya" (Booth et al. 1992: iii). They argue that their decision is based on the failure of a variety of other strategies marshaled to reduce the human-animal conflict. They cite two major reasons for the failure:

> (1) the human population has rapidly expanded leading to a loss of wildlife habitat, and (2) alternative forms of land use have developed as a result of the legal doctrine that all wildlife belongs to the state. (Booth et al. 1992: iii)

Electric fences have been used effectively at many sites in Southern and Eastern Africa to control crop raiding mammals. The cost of these fences runs from US $500 to US $1,500 per km, and the annual maintenance costs are estimated at 30% of the initial capital costs (Booth et al. 1992). Electric fences may be even more expensive to maintain in moist forest environments (Blair and Noor 1979a). Experience elsewhere indicates that the minimum voltage required is 3,000 V, and that it is necessary to kill elephants which persistently break the fence. The literature indicates that constructing such a

fence is futile without the support of local communities to assist in fence maintenance (Booth et al. 1992).

Beyond the obvious, substantial labor and capital costs, a long term environmental cost arises from the insularization of natural habitat. Permanently confining wildlife to a patch of natural habitat results in a loss of genetic diversity and concomitant vulnerability to disease, habitat degradation (if elephant populations grow), and disruption of natural disturbance regimes. Such a conservation strategy resembles zoo management more than ecosystem management.

A profound dilemma now exists in that wildlife at many sites are confined to pockets of habitat in a matrix of densely-settled agriculture. From an ecological perspective, habitat must be expanded to conserve large animals, yet fences are the politically popular answer to a human-wildlife conflict. Fencing should only be considered as a last resort, when the other strategies have failed.

Culling

Killing problem animals has been the standard method of control used throughout Africa. Unless populations are eradicated, control shooting has proven to have very little influence in reducing crop damage (Bell 1984*a;* Balakrishnan and Ndhlovu 1992; Booth et al. 1992; Tchamba 1996) On the other hand, at many sites sharing game meat with local residents has increased public support for conservation (Murombedzi, pers. comm.).

Without even rudimentary data on population dynamics and movement patterns of wildlife such as elephants, bushpigs and baboons at Kibale, it is premature to recommend culling.

Research Suggestions

Wildlife foraging in agricultural landscapes has not captured the attention of field biologists until relatively recently (Else 1991). For example, during 25 years of research at Kibale, bushpigs, elephants, and baboons have scarcely been studied, despite the fact that these are the animals foremost in the minds of Kibale's neighbors. This may be due to the fact that these animals are elusive and far-ranging, and in part, to the perception that crop raiding is an unnatural behavior.

This situation is being remedied as systematic studies of wildlife crop raiding are currently underway at several national parks in Africa. On the basis of my experience at Kibale, I offer several suggestions for studies seeking to measure or predict the pattern of crop loss around parks or reserves.

It is not sufficient to rely on interviews alone, as complaints of damage are frequently exaggerated by farmers seeking compensation, or a legitimate topic to voice their frustration over other concerns (Mwathe 1992; Edmunds, pers. comm.). Even public institutions assigned responsibility for managing crop loss to wildlife have been known to misrepresent the problem for bureaucratic or budgetary advantage (Booth et al. 1992; Mwathe 1992).

An individual researcher seeking to record the foraging behavior of an array of animals of greatly different sizes, ranges, behavior, and ecology faces methodological challenges. Defining the vicinity of dependence for each animal is a logical first step. To illustrate the biological significance of the vicinity of dependence for each animal, take the following example. A strike by animal x at 300 m from a second strike by animal x on the same day would be considered a single event if animal x were an elephant whereas, if the

damage was caused by chimpanzees, these two events would be considered independent (Chapter 3). The sample size for elephants is therefore reduced substantially by this method (71 records reduced to 34 independent events), and each event may damage several farms. The distance used as criterion for determining independence is taken directly from the actual probabilities of strikes known to be independent occurring in the same area.

This conservative method of defining a vicinity of dependence more accurately reflects animal behavior than do studies which tally frequency of raiding by the reports of individual farmers. Ideally, future studies would use similar or otherwise transparent definitions of independence. This would allow more accurate comparison of wildlife damage between different national parks where farm size and population density may vary greatly.

Another methodological challenge is the accurate measurement of crop damage. Results of this study show that for chimpanzees, cercopithecines and smaller mammals, frequency of damage is a relatively accurate measure of amount of damage. In other words, for these animals, it is sufficient to maintain a simple tally of damage events. For other animals, (elephants, baboons, and bushpigs) the amount of crops damaged in each event should be recorded as well as frequency.

Predicting damage is particularly difficult in socially and biologically complex landscapes due to collinearity of variables. For example, univariate analysis showed that guarding was correlated with baboon damage, but multivariate analysis eliminated this variable in favor of distance to the forest. This occurred because people guard more intensely near the forest. Similarly, sight distance is low near the forest boundary because fallow is disproportionately represented there. This covariance reveals a fascinating

interplay of cause and effect in raiding behavior by animals and defensive behavior by humans. The elimination of one variable through multiple regression analysis does not indicate that the variable is useless, for it still may remain as a useful proximate indicator without being causally related. In addition, control for some variables may not eliminate them from analysis: for instance, both univariate and multivariate analysis showed that field size influenced the amount of damage by elephants, even though the response variable was damage per unit area. This complicates the choice and testing of predictor variables, especially for large animals which raid infrequently. The analyses done here were correlative, not causal, but the corroborating evidence gained through interviews with farmers, direct observations and interspecific comparisons strengthen claims of causality for certain variables, such as distance from the forest (Chapter 3)

Finally, considering the variation between sites revealed in this study, caution is warranted in the generalization or dissemination of results from a single site for an entire park. For example, at Kibale, research in the immediate vicinity of the field station is insufficient and even misleading for describing conditions at the park level. Near the field station baboons and elephants are relatively low, human population density is relatively high and farmers practice little guarding or hunting. Beyond the need to sample over several sites, the accurate depiction of raiding behavior requires long term study, particularly in the case of elephants. To be able to understand and predict the foraging patterns of elephants at Kibale, data must be collected over several years.

Conclusions

No single management strategy will stop crop loss to wildlife. In fact, the goal of management should not be to strictly control the problem, but rather to raise general tolerance of wildlife among the farmers, enhance their methods of defense and lessen the impact of severe losses by elephants.

On the technical front, testing of appropriate buffer crops should continue. Ideally, such trials would be carried out in the fields of local farmers with their full participation. Farmers at Isule proved to be particularly cooperative in crop trials undertaken in this study on the effect of eucalyptus as a buffer (unpub. data). At Isule, farmers volunteered their labor and plots of land, while I paid for the beans and maize used in the trial. Farmers at Nkingo have also agreed to contribute land and labor for buffer trials of coffee or other crops. Conclusive results from such trials require careful design of experimental plots and adequate replicates to deal with the existing variation in frequency, timing and extent of damage.

Crisis intervention is currently only necessary along the northern edges of Kibale where elephant forays are frequent. Exploratory discussions with the local tea company about planting fuelwood or tea on the boundary at these sites should be initiated. Purchasing the land of farmers who have lost their crops repeatedly and who wish to sell should be considered. Land prices on the forest edge are not high (roughly US$52 per acre) but the risks of sounding the alarm of eviction among the local community should not be taken lightly.

Uganda National Park Service has taken the first steps toward building long term local support and responsibility for Kibale by helping to build local

conservation councils among the parishes at the forest edge (Rwetsiba, A., UNP, pers. comm.). Eventually it is hoped that these councils will negotiate resource access issues, receive and allocate tourism revenue and help guard Kibale from resource use by outsiders. Environmental education programs should focus on supporting these councils. Outreach and extension programs should also take into account that the closest neighbors of Kibale have distinct attributes in terms of ethnicity, land tenure and wealth. Bakiga immigrants are disproportionately settled on Kibale's edge, and there is greater tendency to acquire land parcels on the edge of the forest via cash purchase than inheritance. Bakiga farms tend to be larger than average on Kibale's edge whereas Batoro farms tend to be smaller than average. The farmers capacity to cope with crop loss is likely to vary accordingly.

Given the high population densities and the typically individualistic strategies of farmers neighboring Kibale, managers aiming to build local community participation in conservation at Kibale face great challenges relative to sites elsewhere in Africa where local management of wildlife has been successful. For example, the CAMPFIRE program in Zimbabwe operates in extensive areas with low human population density which are adjacent to, not within, national parks. At some of these sites, electric fences are constructed around islands of settlements (Booth et al. 1992).

Nonetheless, certain conditions are promising for building legitimate local support for Kibale:

a) crop loss is confined to a relatively narrow band of farmers, this offers managers a target group for their efforts to share benefits, including growing tourism revenue;

b) at the park level, elephant damage at Kibale is relatively low compared to other forest sites, and no one has been killed by elephants (e.g., Aberdares or Shimba Hills in Kenya: Kanuhi, 1995; Mwathe, 1992);

c) the current government of Uganda supports environmental protection and local participation, and park staff at Kibale consider it a priority (Rwetsiba, A., UNP, pers. comm.); and finally,

d) the system of local governance (Resistance Councils) promoted by the national government is functioning relatively well in western Uganda, allowing park managers the opportunity to negotiate with legitimate local institutions regarding rights and responsibilities to Kibale National Park.

APPENDIX

Questionnaire

Date:_____Interviewer:_____Village:_____Time:_____

A. Background information

1. Age, sex and tribe of respondent:

2 Age, sex, # of household members:

3. Household composition: (# wives, or ♀-headed household, # children)

4. How many years residing on this farm?

5. Location of previous residence?

6. Condition of farm when acquired? (cultivated, fallow or forest)

7. Land tenure system: a. kibanja (family), b. kibanja (chief), c. kuha (gift), d. kupangisha, e. itakaeripimirwe, f. kugura

8. Land holdings elsewhere?

9. Size of farm: a. < 0.5 ha, b. 0.5-3 ha, c. >3 ha

10. Distance from the forest boundary.

11. Wealth indicators: a. tea plantation, b. employs laborers, c. coffee plantation, d. cattle (#), e. owning a tin roof, f. owning small livestock (#)

12. Do any household members have outside employment?

13. Are any household members employed with Kibale Forest?

B. Perceptions of crop raiding problem

1. Do animals come to your farm to eat crops?

2. What animals come?

3. When did the last event happen? Describe:

4. What is the worst animal?

5. What crops are most eaten?

6. Is there a crop you cannot plant because of crop raiding?

7. Is there any part of your farm you can't use because of crop raiding?

8. Is the problem getting better or worse?

9. What can you do about the problem?

10. What methods do other farmers use?

11. (If guarding), Who guards?_____ How much?_____

Is anyone guarding right now?

12. Does anyone help you with this problem?

13. (if government mentioned), What do you think the government should do about the problem?

14. Additional comments:

C. Attitudes toward Kibale National Park

1. Why is Kibale Forest being protected?

2. Who benefits from Kibale Forest?

3. Do local people benefit from Kibale Forest? How?

4. Have you heard that Kibale Forest is becoming a National Park? What do you think about that?

LIST OF REFERENCES

Aboud, A. A. 1986. Integrating wildlife resources with human needs. Pages 10-22 in I. MacMillan, ed. Proceedings of the Wildlife/Livestock Interfaces on Rangelands Conference, USAID, Nairobi.

Acord, B. R., C. A. Ramey and R. W. Werge. 1994. Charting a future: Process and promise. Pages 5-8 in W. S. Halverson and A. C. Crabb, eds. Proceedings of the Sixteenth Vertebrate Pest Conference, University of California, Davis, Santa Clara, California.

Adams, J. S. and T. O. McShane. 1992. The Myth of Wild Africa. W.W. Norton & Co., New York.

Aerni, M. J. 1969. Wildlife conservation in Uganda: Field research for Ugandan National Parks. Field report, Rockefeller Brothers Fund, Kampala.

Altman, J. and P. Muruthi. 1988. Differences in daily life between semiprovisioned and wild-feeding baboons. American Journal of Primatology 15:213-221.

Aluma, J., C. Drennon, J. Kigula, S. W. Lawry, E. S. K. Muwanga-Zake and J. Were. 1989. Settlement in forest reserves, game reserves, and national parks in Uganda. Makerere Institute of Social Research, Kampala.

Anonymous. 1994. Firing Line. The Weekly Review. January 14. pp.3-10.

Anstey, S. 1991. Wildlife utilisation in Liberia. World Wildlife Fund/FDA, Dorchester, U.K.

Bahuchet, S. and I. Garine. 1990. The art of trapping in the rainforest. Pages 24-25 in C. M. Hladik, S. Bahuchet and I. Garine, eds. Food and Nutrition in the African Rainforest. UNESCO, Paris.

Balakrishnan, M. and D. E. Ndhlovu. 1992. Wildlife utilization and local people: A case-study in Upper Lupande Game Management Area, Zambia. Environmental Conservation 19(2):135-144.

Baldus, R. D. 1988. Conflicts between wildlife and people: Village development planning for three settlements bordering the Selous Game Reserve. GTZ, Dar es Salaam.

Baldwin, J. D. and J. I. Baldwin. 1976. Primate populations in Chiriqui, Panama. Pages 20-31 in R. W. Thorington and P. G. Heltne, eds. Neotropical Primates: Field Studies and Conservation. National Academy of Sciences, Washington, D.C.

Baranga, D. 1993. The ecology and conservation status of the redtail monkey (*Cercopithecus ascanius schmidti*) in the Kampala area. Ph.D. Thesis, Makerere University, Kampala, Uganda.

Barnes, R. F. W. 1990. Famine in the rainforest. Wildlife Conservation International, Bronx, New York.

Bell, R. H. V. 1984*a*. The man-animal interface: An assessment of crop damage and wildlife control. Pages 387-416 in R. H. V. Bell and E. McShane-Caluzi, eds. Conservation and Wildlife Management in Africa. U.S. Peace Corps Office of Training and Program Support, Malawi.

Bell, R. H. V. 1984*b*. Monitoring of public attitudes. Pages 442-448 in R. H. V. Bell and E. McShane-Caluzi, eds. Conservation and Wildlife Management in Africa. U.S. Peace Corps Office of Training and Program Support, Malawi.

Bell, R. H. V. 1987. Conservation with a human face. Pages 79-101 in R. Anderson and R. Grove, eds. Conservation in Africa. Cambridge University Press, Cambridge, England.

Ben-David, K. 1995. Fruiting pattern in Kibale National Park, Uganda: Relationships with rainfall and temperature. Senior Honors Thesis, University of Florida, Gainesville.

Blair, J. A. S. 1979. Elephants and other animal pests. Pages 1-13 in J. R. Blair and N. M. Noor, eds. Proceedings of the Incompatible Neighbors: Workshop on Elephant Damage. INPUT, Institute of Land Development, Trolak, Perak, Malaysia.

Blair, J. R. and N. M. Noor. 1979a. Initial report on feasibility of preventive measures. Pages 14-29 in J. R. Blair and N. M. Noor, eds. Proceedings of the Incompatible Neighbors: Workshop on Elephant Damage. INPUT, Institute of Land Development, Trolak, Perak, Malaysia.

Blair, J. R. and N. M. Noor. 1979*b*. The Malaysian elephant: its characteristics and behavior. Pages 34-43 in J. R. Blair and N. M. Noor, eds. Proceedings of the Incompatible Neighbors: Workshop on Elephant Damage. INPUT, Institute of Land Development, Trolak, Perak, Malaysia.

Blair, J. R. and N. M. Noor. 1979*c*. Epilogue to elephant damage workshop. Pages 232-248 in J. R. Blair and N. M. Noor, eds. Proceedings of the Incompatible Neighbors: Workshop on Elephant Damage. INPUT, Institute of Land Development, Trolak, Perak, Malaysia.

Bonner, R. 1993. At the Hand of Man--Peril and Hope for Africa's Wildlife. Knopf, New York.

Boon, G. G. 1979. Evaluating elephant damage in oil palm areas. Pages 44-66 in J. R. Blair and N. M. Noor, eds. Proceedings of the Incompatible Neighbors: Workshop on Elephant Damage. INPUT, Institute of Land Development, Trolak, Perak, Malaysia.

Booth, V. R., N. N. Kipuri and J. M. Zonneveld. 1992. Environmental impact of the proposed fencing programme in Kenya. Elephant and Community Wildlife Programme, Kenya Wildlife Service, Nairobi.

Brooke, J. 1996. Yellowstone wolves get an ally in tourist trade. New York, New York.

Brooks, A. C. and I. O. Buss. 1962. Past and present status of the elephant in Uganda. Journal of Wildlife Management 26(1):38-50.

Brown, L. H. 1981. The conservation of forest islands in areas of high human density. African Journal of Ecology 19:27-32.

Brown, M., R. Buckley, A. Singer and L. Dawson. 1992. Buffer zone management in Africa. PVO-NGO/NRMS Project of USAID, Washington, D.C.

Burton, I., R. W. Kates and G. F. White. 1978. The Environment as Hazard. Oxford University Press, New York.

Butynski, T. M. 1984. Ecological survey of the Impenetrable (Bwindi) Forest, Uganda, and recommendations for its conservation and management. Wildlife Conservation International, New York Zoological Society, Bronx, New York.

Butynski, T. M. 1990. Comparative ecology of blue monkeys (*C. mitis*) in high- and low-density subpopulations. Ecological Monographs 60(1):1-26.

Caldecott, J. 1988. Hunting and Wildlife Management in Sarawak. International Union for the Conservatin of Nature, Gland, Switzerland.

CARE. 1994. The people of Bwindi Impenetrable National Park. CARE, Kabale, Uganda.

Chambers, R. 1991. Shortcut and participatory methods for gaining social information for projects. Pages 515-537 in M. M. Cernea, ed. Putting People First. Sociological Variables in Rural Development. Oxford University Press, Washington, D.C.

Chapman, C. A., L. J. Chapman, R. Wrangham, G. Isabirye-Basuta and K. Ben-David. in prep. Spatial and temporal variability in the structure of a tropical forest.

Chapman, C. A. and R. W. Wrangham. 1993. Range use of the forest chimpanzees of Kibale: Implications for the understanding of chimpanzee social organization. American Journal of Primatology 31:263-273.

Chapman, C. A. and R. W. Wrangham. in prep. Spatial and temporal variation in chimpanzee food resources: Implications for grouping.

Chapman, C. A., R. W. Wrangham and L. J. Chapman. 1995. Ecological constraints on group size: An analysis of spider monkey and chimpanzee subgroups. Behavioural Ecology and Sociobiology 36:59-70.

Chapman, L. J., C. A. Chapman and R. W. Wrangham. 1992. *Balanites wilsoniana*: Elephant dependent dispersal. Journal of Tropical Ecology 8:275-283.

Christensen, N. L., A. Bartuska, J. H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J. F. Franklin, J. A. MacMahon, R. F. Noss, D. J. Parsons, C. H. Peterson, M. G. Turner and R. G. Woodmansee. 1995. Scientific basis for ecosystem management. Ecological Society of America, U.S.A.

Clay, J. 1988. Indigenous Peoples and Tropical Forests. Cultural Survival, Inc., Cambridge, Massachusetts.

Conover, M. R. 1988. Effect of grazing by Canada geese on the winter growth of rye. Journal of Wildlife Management 52:76-80.

Conover, M. R. 1994. Perceptions of grass-roots leaders of the agricultural community about wildlife damage on their farms and ranches. Wildlife Society Bulletin 22:94-100.

Crosby, A. W. 1986. Ecological Imperialism: the Biological Expansion of Europe, 900-1900. Cambridge University Press, Cambridge.

Damiba, T. E. and E. D. Ables. 1993. Promising future for an elephant population - A case study in Burkina Faso. Oryx 27(2):97-103.

Donkin, R. A. 1985. The Peccary: With observation on the Introduction of Pigs to the New World. American Philosophical Society, Philadelphia, PA.

Dove, M. R. 1993. The responses of Dayak and bearded pig to mast-fruiting in Kalimantan: An analysis of nature-culture analogies. Pages 113-123 in C. M. Hladik, A. Hladik, O. F. Linares, H. Pagezy, A. Semple and M. Hadley, eds. Tropical Forests, People and Food: Biocultural Interactions and Application to Development. Parthenon Publishing, Paris.

Dow, K. 1992. Exploring differences in our common future(s): The meaning of vulnerability to global environmental change. Geoforum 23:417-436.

Dublin, H. T. 1995. Chairman's report: African elephant specialist group. Pachyderm 20:8-9.

Dudley, J. P., A. Y. Mensah-Ntiamoah and D. G. Kpelle. 1992. Forest elephants in a rainforest fragment: Preliminary findings from a wildlife conservation project in southern Ghana. African Journal of Ecology 30:116-126.

Edmunds, D. 1994. Report on preliminary findings from a study of local resource management institutions near the Kibale Forest National Park. Makerere Institute of Social Research, Land Access Program, Kampala, Uganda.

Else, J. G. 1991. Nonhuman primates as pests. Pages 155-165 in H. O. Box, ed. Primate Responses to Environmental Change. Chapman and Hall, London.

Estes, R. D. 1991. The Behavior Guide to African Mammals. The University of California Press, Berkeley, CA.

Fiallo, E. A. and S. K. Jacobson. in press. Local communities and protected areas: Attitudes of rural residents toward conservation and Machalilla National Park, Ecuador. Environmental Conservation.

Forbes, L. P. F. 1991. Cambridge-Uganda forest island expedition 1991. Cambridge University, Cambridge, U.K.

Ganzhorn, J. U. and J.-P. Abraham. 1991. Possible role of plantations for lemur conservation in Madagascar: Food for folivorous species. Folia Primatologica 56:171-176.

Gesicho, A. 1991. A survey of the Arabuko Sokoke elephant population. KWS Elephant Programme, Nairobi, Kenya.

Ghiglieri, M. P., T. M. Butynski, T. T. Struhsaker, L. Leland, S. J. Wallis and P. Waser. 1982. Bush pig (*Potamochoerus porcus*) polychromatism and ecology in Kibale Forest, Uganda. African Journal of Ecology 20:231-236.

Gliessman, S. R., Ed. 1990. Agroecology: Researching the Ecological Basis for Sustainable Agriculture. Springer-Verlag, Berlin, Germany.

Goldman, A. C. 1986. Pest hazards and pest management by small scale farmers in Kenya. Ph.D. Thesis, Clark University, Worcester, Massachusetts.

Graham, A. D. 1973. The Gardeners of Eden. George Allen & Unwin Ltd., London.

Graham, R. T., J. L. Kingery and L. A. Volland. 1992. Livestock and forest management interactions. Pages 351-364 in H. C. Black, ed. Silvicultural Approaches to Animal Damage in Pacific Northwest Forests. United States Department of Agriculture, Forest Service, Portland, Oregon.

Greenhood, W. F. 1971. Diets and ecology of crop-raiding baboons. Masters Thesis, University of Florida, Gainesville.

Grubb, P. 1993. The afrotropical suids, Phacochoerus, Hylochoerus, and Potamochoerus. Taxonomy and description. Pages 34-37 in W. L. R. Oliver, ed. Pigs, Peccaries and Hippos. International Union for the Conservation of Nature, Gland, Switzerland.

Halverson, W. S. and A. C. Crabb, Eds. 1994. Proceedings of the Sixteenth Vertebrate Pest Conference. University of California, Davis.

Hamilton, A. C. 1981. The quaternary history of African forests: Its relevance to conservation. African Journal of Ecology 19:1-6.

Hamilton, A.C. 1984. Deforestation in Uganda. Oxford University Press, Nairobi.

Hammer, J. and J. Contreras. 1995. Under pressure. Newsweek International. September 18. p.26.
Harcourt, A. H., H. Pennington and A. W. Weber. 1986. Public attitudes to wildlife and conservation in the Third World. Oryx 20(3):152-154.

Harrison, R. P. 1992. Forests. The Shadow of Civilization. University of Chicago Press, Chicago.

Harvey, P. H., R. D. Martin and T. H. Clutton-Brock. 1987. Life histories in comparative perspective. Pages 181-196 in B. Smuts, D. L. Cheney, R. M. Seyfarth, R. W. Wrangham and T. T. Struhsaker, eds. Primate Societies. University of Chicago Press, Chicago.

Hawkes, R. K. 1991. Crop and livestock losses to wild animals in the Bulilimamangwe Natural Resources Management Project Area. Working paper in series funded by USAID Natural Resources Management Project, Center for Applied Social Sciences, University of Zimbabwe, Harare.

Heberlein, T. A. 1981. Environmental attitudes. Zeitschrift fur Umweltpolitik 2:241-269.

Hill, C. M. 1993. Crop-raiding by wildlife: Its impact on a farming community in Uganda. Institute of Biological Anthropology, University of Oxford, Oxford, U.K.

Hillebrecht, K. and J. Woellecke. 1992. Comparison of monkey-populations at the edge of the forest. Technische Universität Braunschweig, Germany.

Holling, C. S. 1986. The resilience of terrestrial ecosystems: Local surprise and global change. Pages 292-317 in W. C. Clark and R. E. Munn, eds. Sustainable Development of the Biosphere. Cambridge University Press, Cambridge, U.K.

Horrocks, J. A. and J. Baulu. 1988. Effects of trapping on the vervet (*Cercopithecus aethiops sabaeus*) population in Barbados. American Journal of Primatology 15:223-233.

Horrocks, J. A. and W. Hunte. 1986. Sentinel behaviour in vervet monkeys: Who sees whom first? Animal Behaviour 34(5):1566-1567.

Howard, P. C. 1991. Nature Conservation in Uganda's Tropical Forest Reserves. International Union for the Conservation of Nature, Gland, Switzerland.

Hyden, G. and M. Bratton. 1992. Governance and Politics in Africa. Lynne Rienner Publishers, Boulder.

Hygnstrom, S. E., K. C. Vercauteren and T. R. Schmaderer. 1994. Biological management (control) of vertebrate pests--Advances in the last quarter century. Pages 293-300 in W. Halverson and A. C. Crabb, eds. Proceedings of the Sixteenth Vertebrate Pest Conference, University of California, Davis, Santa Clara.

International Institute on Environment and Development (IIED). 1988. An Introduction to rapid rural appraisal for agricultural development. IIED, Washington, D.C.

Ingham, K. 1978. The Kingdom of Toro in Uganda. Methuen & Co., Ltd., London, U.K.

Isabirye-Basuta, G. n.d. Some of the problems related to the conservation of Chimpanzees (*Pan troglodytes*) in Kibale Forest, Uganda. Department of Zoology, Makerere University, Kampala, Uganda.

Johnsingh, A. J. T. and H. S. Panwar. 1989. Elephant conservation in India - Problems and prospects. Pages 36-51 in P. Wegge, ed. Mammal Conservation in Developing Countries. NORAGRIC, Oslo, Norway.

Kaipiriri, M. in prep. Local use of non-timber forest products. Master's Thesis, Makerere University, Kampala, Uganda.

Kamarudin, K. A. and C. H. Lee. 1989. Rat spatial distribution pattern and its relation to pod damage in a cocoa-coconut planting system. MARDI Research Journal 17(1):75-89.

Kanuhi, S. 1995. Elephant crop raiding around Aberdares National Park. Master's Thesis, Moi University, Nairobi, Kenya.

Kasperson, R. E., O. Renn, P. Slovic, H. Brown, J. Emel, R. Globe, J. X. Kasperson and S. J. Ratnik. 1988. The social amplification of risk: A conceptual framework. Risk Analysis 8(2):177-187.

Kavanagh, M. 1980. Invasion of the forest by an African savannah monkey: Behavioral adaptations. Behaviour 73:238-260.

Kingdon, J. S. 1979. East African Mammals. Academic Press, London, U.K.

Kingston, B. 1967. Working plan for the Kibale and Itwara Central Forest Reserves, 2nd edition. Uganda Government Forest Department, Kampala, Uganda.

Kiss, A. 1990. Living with wildlife. Wildlife resource management and local participation in Africa. World Bank Technical Paper Number 130/Africa Technical Department Series, Washington, D.C.

Kramer, S. N. 1963. The Sumerians. University of Chicago Press, Chicago.

Lahm, S. A. 1994. The impact of elephants and other wildlife on agriculture in Gabon. African Elephant Conservation Coordinating Group/EC, Libreville, Gabon.

Lahm, S. A. 1995. Survey of crop raiding animals. Gnusletter 14(2&3):22-3.

Lee, P. C., E. J. Brennan, J. G. Else and J. Altmann. 1986. Ecology and behaviour of vervet monkeys in a tourist lodge habitat. Pages 229-235 in J. G. Else and P. C. Lee, eds. Primate Ecology and Conservation. Cambridge University Press, Cambridge, U.K.

Leggat, G. J. 1956. Informal letter regarding elephant damage in forest reserves. National Office of Forest Department, Kampala, Uganda.

Leggat, G. J. 1965. The reconciliation of forestry and game preservation in western Uganda. East African Agricultural and Forestry Journal 30:355-369.

Letourneau, D. K. 1990. Two examples of natural enemy augmentation: A consequence of crop diversification. Pages 11-29 in S. R. Gliessman, ed. Agroecology: Researching the Ecological Basis for Sustainable Agriculture. Springer-Verlag, Berlin, Germany.

Lewis, D. M. 1988. Survey of perceptions toward wildlife for two village communities with different exposure to a wildlife conservation project. Research report, Zambia National Parks and Wildlife Services, Lusaka.

Linares, O. F. 1976. Garden hunting in the American tropics. Human Ecology 4(4):331-349.

Litoroh, M., J. Sakwa, P. Omondi and M. Reuling. 1992. A survey of the Marmanet Forest Complex. Elephant and large mammal populations. Kenya Wildlife Service/EC, Nairobi, Kenya.

Little, P. D. and D. W. Brokensha. 1987. Local institutions, tenure and resource management in East Africa. Pages 193-210 in D. Anderson and R. Grove, eds. Conservation in Africa. Cambridge University Press, Cambridge, U.K.

Liverman, D. 1990. Vulnerability to global environmental change. Pages 27-44 in R. E. Kasperson, ed. Understanding Global Environmental Change. The Earth Transformed Program, Worcester, Mass.

Lund, T. A. 1980. American Wildlife Law. University of California Press, Berkeley.

Malpas, R. 1980. Wildlife in Uganda, 1980 -- A report to the Minister of Tourism and Wildlife, Uganda. New York Zoological Society/World Wildlife Fund/International Union for the Conservation of Nature, Kampala, Uganda.

Maples, W. R., M. K. Maples, W. F. Greenhood and M. L. Walek. 1976. Adaptations of crop-raiding baboons in Kenya. American Journal of Physical Anthropology 45:309-316.

Marks, S. A. 1976. Large Mammals and a Brave People. University of Washington Press, Seattle.

Marks, S. A. 1984. The Imperial Lion: Human Dimensions of Wildlife Management in Central Africa. Westview Press, Boulder, Colo.

Martin, E. B. and L. Vigne. 1995. Nepal's rhinos - One of the greatest conservation success stories. Pachyderm 20:10-26.

Martin, R. B. 1984. Wildlife human interactions. Pages 209-217 in R. H. V. Bell and E. McShane-Caluzi, eds. Conservation and Wildlife Management in Africa. U.S. Peace Corps Office of Training and Program Support, Malawi.

Masau, J. M. and S. C. Strum. 1984. Response of wild baboon troops to incursion of agriculture at Gilgil, Kenya. International Journal of Primatology 5:364.

Medellin, R. A. and K. H. Redford. 1992. The role of mammals in neotropical forest-savanna boundaries. Pages 519-548 in P. A. Furley, J. Proctor and J. A. Ratter, eds. Nature and Dynamics of Forest-Savanna Boundaries. Chapman & Hall, London, U.K.

Milton, J. P. and G. A. Binney. 1980. Ecological planning in the Nepalese Terai. World Wildlife Fund and Sierra Club Foundation, Threshold, International Center for Environmental Renewal, Washington, D.C.

Moe, S. R., E. B. Kapela and P. Wegge. 1989. Land use conflicts at national park borders: A case study of Lake Burungi Area in Tanzania. Pages 101-105 in P. Wegge, ed. Mammal Conservation in Developing Countries, vol. 11. NORAGRIC, Oslo.

Mohnot, S. M. 1971. Ecology and behaviour of the Hanuman langur, *Presbytis entellus*, invading fields, gardens and orchards around Jodhpur, Western India. Tropical Ecology 12(2):237-249.

Moore, J. 1992. Savanna chimpanzees. Pages 99-118 in T. Nishida, W. C. McGrew, P. Marler, M. Pickford and F. B. M. de Waal, eds. Topics in Primatology, 1. Human Origins. University of Tokyo Press, Tokyo, Japan.

Muganga, J. 1990. Interactions between wildlife and human communities around Kibale Forest Reserve. 6-month project progress report, Makerere University Biological Field Station, Kibale Forest, Uganda.

Muganga, J. and G. Isabirye-Basuta. 1990. Reports on crop raiding by wildlife, Kisinga Village. Makerere University Biological Field Station, Kibale Forest, Uganda.

Mugisha, S. 1994. Land cover/use around Kibale National Park. Analysis of 1988 aerial photographs. Uganda Forestry Department (Sheet No. BP 1939), MUIENR, RS/GIS Lab, Kampala, Uganda.

Mwathe, K. M. 1992. A preliminary report on elephant crop damage in areas bordering Shimba Hills National Reserve. Kenya Wildlife Service Elephant Program, Nairobi.

Naughton-Treves, L. and S. Sanderson. 1995. Property, politics and wildlife conservation. World Development 23(8):1265-1275.

Newmark, W. D. 1985. Legal and biotic boundaries of western North American national parks: A problem of congruence. Biological Conservation 33:197-208.

Newmark, W. D. 1995. Extinction of mammal populations in western North American national parks. Conservation Biology 9(3):512-526.

Newmark, W. D. and N. L. Leonard. 1991. Attitudes of local people toward Kilimanjaro National Park and Forest Reserve. Pages 87-96 in W. D. Newmark, ed. The Conservation of Mount Kilimanjaro. International Union for the Conservation of Nature, Gland, Switzerland.

Newmark, W. D., D. N. Manyanza, D.-G. M. Gamassa and H. I. Sariko. 1994. The conflict between wildlife and local people living adjacent to protected areas in Tanzania: Human density as a predictor. Conservation Biology 8(1):249-255.

Nganzi, P. B. 1994. The socio-economic impact of Kibale Tree-Planting Project and Conservation Education Project on the local population. Survey, Makerere International Institute of Environmental Education, Kampala, Uganda.

Niemeyer, C. C., E. E. Bangs, S. H. Fritts, F. A. Fontaine, M. D. Jimenez and W. G. Brewster. 1994. Wolf depredation management in relation to wolf recovery. Pages 57-59 in W. S. Halverson and A. C. Crabb, eds. Proceedings of the Sixteenth Vertebrate Pest Conference. University of California, Davis, Santa Clara.

Noss, A. J. 1995. Duikers, cables, and nets: A cultural ecology of hunting in a Central African forest. Ph.D. Dissertation, University of Florida, Gainesville.

Nummelin, M. 1990. Relative habitat use of duikers, bush pigs, and elephants in virgin and selectively logged areas of the Kibale forest, Uganda. Tropical Zoology 3:111-120.

Osborn, F. V. 1993. The ecology and deterrence of crop raiding elephants. Department of National Parks and Wildlife Management, Harare, Zimbabwe.

Osmaston, H. A. 1959. Working plan for the Kibale and Itwara Central Forest Reserves, Toro District, W. Province, Uganda. Report #1, Forest Department, Uganda Protectorate, Kampala.

Ostrom, E. 1990. Governing the Commons. Cambridge University Press, Cambridge, MA.

Owens, M. and D. Owens. 1984. Cry of the Kalahari. Houghton Mifflin, Boston.

Palm, R. I. 1990. Natural Hazards. Johns Hopkins University Press, Baltimore.

Parker, I. S. C. 1984. The nature of the interaction between humans and wildlife. Pages 201-205 in R. H. V. Bell and E. McShane-Caluzi, eds. Conservation and Wildlife Management in Africa. U.S. Peace Corps Office of Training and Program Support, Washington, D.C.

Perrings, C. A., K.-G. Maler, C. Folke, C. S. Holling and B.-O. Jansson. 1995. Biodiversity conservation and economic development: The policy problem. Pages 3-21 in C. A. Perrings, K.-G. Maler, C. Folke, C. S. Holling and B.-O. Jansson, eds. Biodiversity Conservation. Kluwer Academic Publishers, Amsterdam, Netherlands.

Peters, R. L. and T. E. Lovejoy. 1990. Terrestrial fauna. Pages 353-371 in B. L. Turner, W. C. Clark, R. W. Kates, J. F. Richards, J. T. Mathews and W. B. Meyer, eds. The Earth as Transformed by Human Action. Cambridge University Press, Cambridge, U.K.

Peveling, R. 1992. Wechselbeziehungen zwischen Weidegangern, Grasern und granivoren Vogeln in agropastoral genutzten Savannensystemen Sud-Somalias. Institut fur Biogeographie, Saarbrucken, Germany.

Pitkin, B. 1995. Protected Area Conservation Strategy (PARCS): Training needs and opportunities among protected area managers in eastern, central, and southern Africa. Biodiversity Support Program, c/o World Wildlife Fund.

Reuling, M., M. Litoroh and J. Sakwa. 1992*a*. A survey of the Mau Forest complex: Elephants and large mammal populations. Kenya Wildlife Service/EC, Nairobi, Kenya.

Reuling, M., U. Matiru, S. Njumbi and M. Litoroh. 1992*b*. Mount Kenya and Mount Elgon forest elephant survey. Kenya Wildlife Service/EC, Nairobi, Kenya.

Reuling, M., K. Mwathe, M. Litoroh and J. Poole. 1992*c*. A survey of the Shimba Hills elephant population. KWS/KIFCON, Nairboi, Kenya.

Riccuiti, E. R. 1995. The iron creek incident. Wildlife Conservation 98(6):50-55.

Richards, P. 1986. Coping with Hunger: Hazard and Experiment in an African Rice-Farming System. Allen & Unwin, Boston, MA.

Robinson, J. and K. Redford, Eds. 1991. Neotropical Wildlife Use and Conservation. University of Chicago Press, Chicago.

Rocheleau, D. E., P. E. Steinberg and P. A. Benjamin. in prep. Environment, development, crisis, and crusade: Ukambani, Kenya, 1890-1990.

Rothchild, D. and N. Chazan. 1988. The Precarious Balance: State and Society in Africa. Westview Press, Boulder, Colo.

Rowell, T. E. 1966. Forest living baboons in Uganda. Journal of the Zoological Society (Lond.) 149:344-365.

Salafsky, N. 1992. Mammalian use of a buffer zone agroforestry system bordering Gunung Palung National Park, West Kalimantan. manuscript, School of the Environment, Duke University, N.C.

Schemnitz, S. D., Ed. 1980. Wildlife Management Techniques Manual, 4th ed. The Wildlife Society, Washington, D.C.

Schule, W. 1992. Vegetation, megaherbivores, man and climate in the Quaternary and the genesis of closed forests. Pages 45-75 in J. G. Goldammer, ed. Tropical Forests in Transition. Birkhauser Verlag, Boston.

Seagle, S. W. and S. J. McNaughton. 1992. Spatial variation in forage nutrient concentrations and the distribution of Serengeti grazing ungulates. Landscape Ecology 7:229-242.

Seidensticker, J. 1984. Managing elephant depredation in agricultural and forestry projects. A World Bank Technical Paper, The World Bank, Washington, D.C.

Skorupa, J. P. 1988. The effects of selective timber harvesting on rainforest primates in Kibale Forest Uganda. Ph.D. Thesis, University of California, Davis.

Southwick, C. H., M. F. Siddiqi and R. Johnson. 1986. Demographic effects of home range displacement on rhesus monkeys at Chhatari, northern India. American Journal of Primatology 10:4333.

Steinhart, E. I. 1971. Transition in western Uganda: 1891-1901. PhD Thesis, Northwestern University, Chicago.

Struhsaker, T. T. 1975. The Red Colobus. University of Chicago Press, Chicago.

Struhsaker, T. T. 1980. Comparison of the behaviour and ecology of red colobus and redtail monkeys in the Kibale Forest, Uganda. African Journal of Ecology 18:33-51.

Struhsaker, T. T. 1981*a*. Forest and primate conservation in East Africa. African Journal of Ecology 19:99-114.

Struhsaker, T. T. 1981*b*. Vocalizations, phylogeny and palaeogeography of red colobus monkeys (*Colobus badius*). African Journal of Ecology 19:265-283.

Struhsaker, T. T. 1981*c*. Polyspecific associations among tropical rain-forest primates. Zeitschrift für Tierpsychologie 57:268-304.

Struhsaker, T. T. 1987. Forestry issues and conservation in Uganda. Biological Conservation 39:209-234.

Struhsaker, T. T. in press. Kibale: A Case Study of Logging in a Tropical Rainforest. University Press of Florida, Gainesville.

Struhsaker, T. T. and L. Leland. 1988. Group fission in redtail monkeys (*Cercopithecus ascanius*) in the Kibale Forest Uganda. Pages 364-388 in A. Gautier-Hion, F. Bourliere, J. P. Gautier and J. Kingdon, eds. A Primate Radiation: Evolutionary Biology of the African Guenons. Cambridge University Press, Cambridge, U.K.

Struhsaker, T. T. and J. F. Oates. 1975. Comparison of the behavior and ecology of red colobus and black-and-white colobus monkeys in Uganda: A summary. Pages 103-123 in R. H. Tuttle, ed. Socio-ecology and Psychology of Primates. Mouton, The Hague.

Strum, S. C. 1987. Almost Human. Elm Tree Books, London, U.K.

Suarez, I. M. T. 1993. Ecologia de los grupos de sainos (*Tayassu tajacu*) y danos que ocasionan en los cultivos vecinos a la Estacion Biologica de la Selva, Costa Rica. Masters Thesis, Universidad Nacional de Costa Rica, Heredia, Costa Rica.

Sukumar, R. 1989. The Asian Elephant. Cambridge University Press, Cambridge, U.K.

Sukumar, R. 1994. Elephant Days and Nights. Oxford University Press, Delhi, India.

Sukumar, R. 1995. Elephant raiders and rogues. Natural History 104(7):52-61.

Sunquist, M. E. 1981. The social organization of tigers (*Panthera tigris*) in Royal Chitawan National Park, Nepal. Smithsonian Contributions to Zoology 336:1-92.

Tabor, G. M., A. D. Johns and J. M. Kasenene. 1990. Deciding the future of Uganda's tropical forests. Oryx 24(4):208-214.

Talbot, L. and P. Olindo. 1990. The Maasai Mara and Amboseli Reserves. Pages 67-74 in A. Kiss, ed. Living with Wildlife, Wildlife Resource Management with Local Participation in Africa. World Bank, Washington, D.C.

Taylor, B. K. 1962. The Western Lacustrine Bantu. Sidney Press, Ltd., London, U.K.

Tchamba, M. N. 1996. History and present status of the human/elephant conflict in the Waza-Logone region, Cameroon, West Africa. Biological Conservation 75:35-41.

Thomas, S. C. 1991. Population densities and patterns of habitat use among anthropoid primates of the Ituri Forest, Zaire. Biotropica 23(1):68-83.

Tuan, Y. F. 1974. Topophilia. Prentice-Hall, Englewood Cliffs, N.J.

Turyahikayo-Rugyema, B. 1974. The history of the Bakiga in southwestern Uganda and northern Rwanda, 1500-1930. PhD Thesis, University of Michigan, Ann Arbor.

Urquhart, D. H. 1961. Cocoa, 2nd ed. Longman Press, London, U.K.

Van Orsdol, K. G. V. 1987. Buffer zone agroforestry in tropical forest regions. Forestry Support Program of USDA Forest Service, Washington, D.C.

Vansina, J. 1990. Paths in the Rainforests. The University of Wisconsin Press, Madison.

Vercammen, P., A. H. W. Seydack and W. L. R. Oliver. 1993. The bush pigs (*Potamochoerus porcus* and *P. larvatus*). Pages 93-101 in W. L. R. Oliver, ed. Pigs, Peccaries and Hippos. IUCN, Gland, Switzerland.

Ville, J.-L. 1995. Man and elephant in the Tsavo area of Kenya: An anthropological perspective. Pachyderm 20:69-72.

Voyles, K. 1994. Some are fighting to end Florida panther program. The Gainesville Sun. December 5. p.4B.

Wakely, J. S. and R. C. Mitchell. 1981. Blackbird damage to ripening field corn in Pennsylvania. Wildlife Society Bulletin 9:52-55.

Waser, P. M. 1974. Intergroup interaction in a forest monkey, the mangabey (*Cercocebus albigena*). Ph.D. Dissertation, Rockefeller University, New York.

Wells, M. and K. Brandon. 1992. People and Parks. World Bank, Washington, D.C.

Western, D. 1989. Conservation without parks: Wildlife in the rural landscape. Pages 158-165, in D. Western and M. Pearl, eds. Conservation for the Twenty-First Century. Oxford University Press, New York.

Western, D. and M. Pearl, Eds. 1989. Conservation for the Twenty-First Century. Oxford University Press, New York.

Wilcox, B. A. 1980. Insular ecology and conservation. Pages 95-118 in M. E. Soule and B. A. Wilcox, eds. Conservation Biology. Sinauer Associates, Inc., Sunderland, Mass.

Wing, L. D. and I. O. Buss. 1970. Elephants and forests. Wildlife Monographs 19:1-92.

World Bank. 1993. Uganda. Agriculture. World Bank Country Study, The World Bank, Washington, D.C.

World Resources Institute. 1994. World Resources 1994-5. Oxford University Press, New York.

Wrangham, R. W. 1977. Feeding behavior of chimpanzees in Gombe National Park, Tanzania. Pages 503-538 in T. H. Clutton-Brock, ed. Primate Ecology. Academic Press, New York.

Wrangham, R. W., N. L. Conklin, C. A. Chapman and K. D. Hunt. 1991. The significance of fibrous foods for Kibale Forest Chimpanzees. Phil. Trans. of the Royal Society of London Series B.(334):171-178.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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